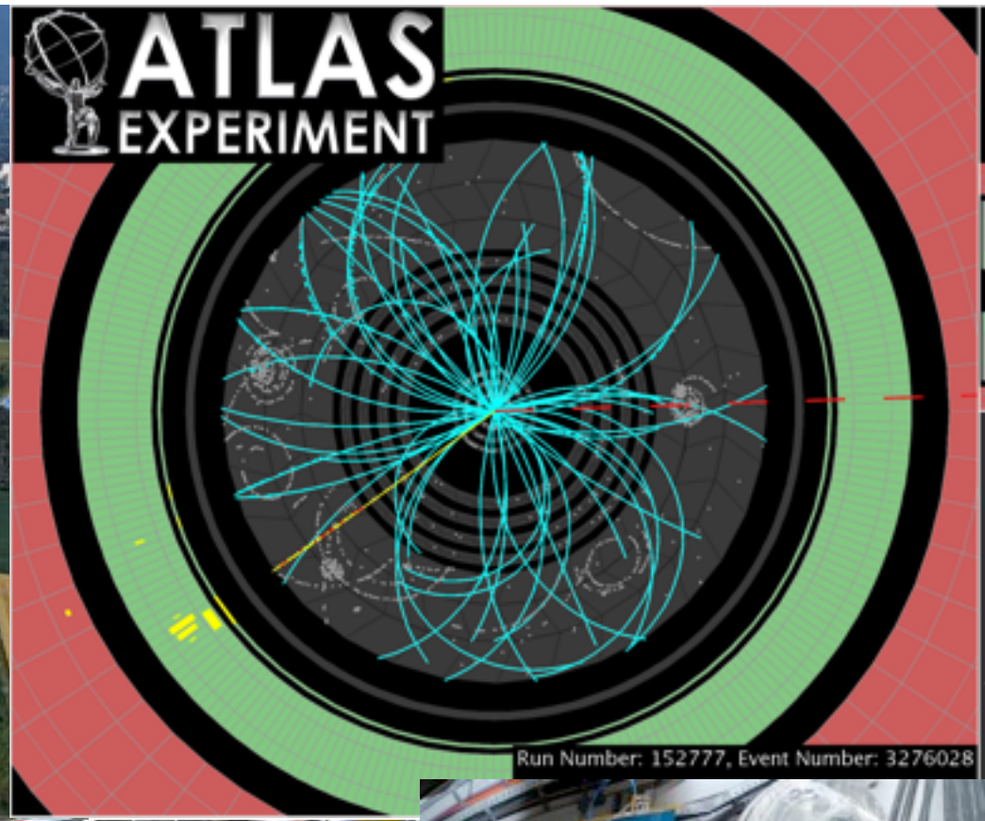
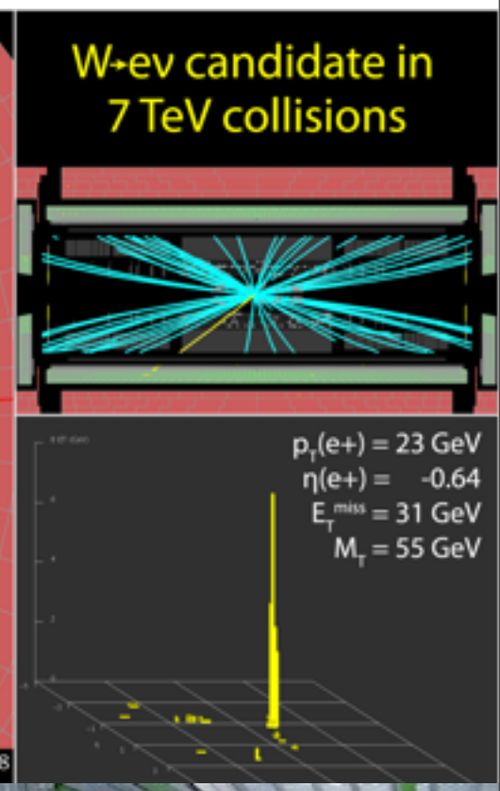
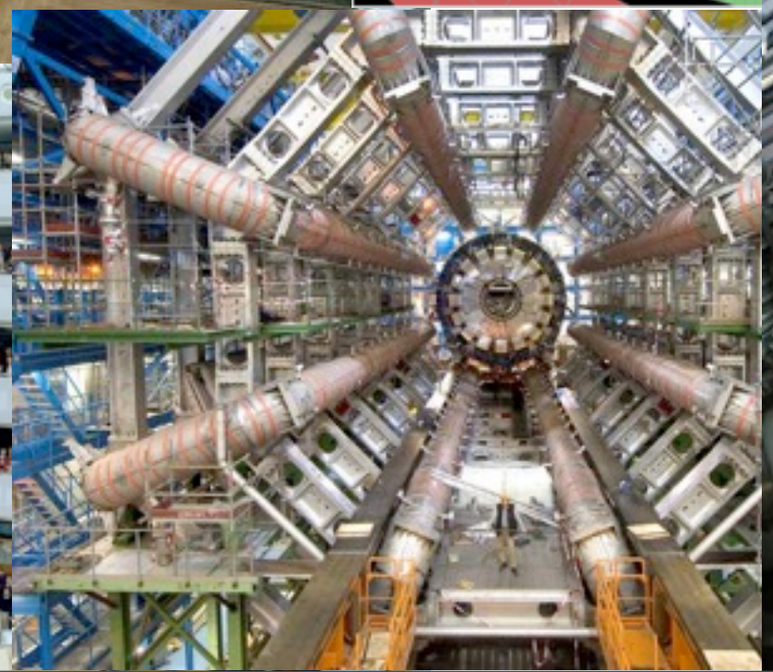
The Higgs and Other Physics of the LHC

Thomas Gadfort
Brookhaven National Laboratory







Overview

the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY

What We Already Know: The Standard Model

Why Do Particles Have Mass?

The Higgs Boson

Overview

the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY

What We Already Know: The Standard Model

Why Do Particles Have Mass?

The Higgs Boson

The Scales In Our World

the ATLAS Experiment

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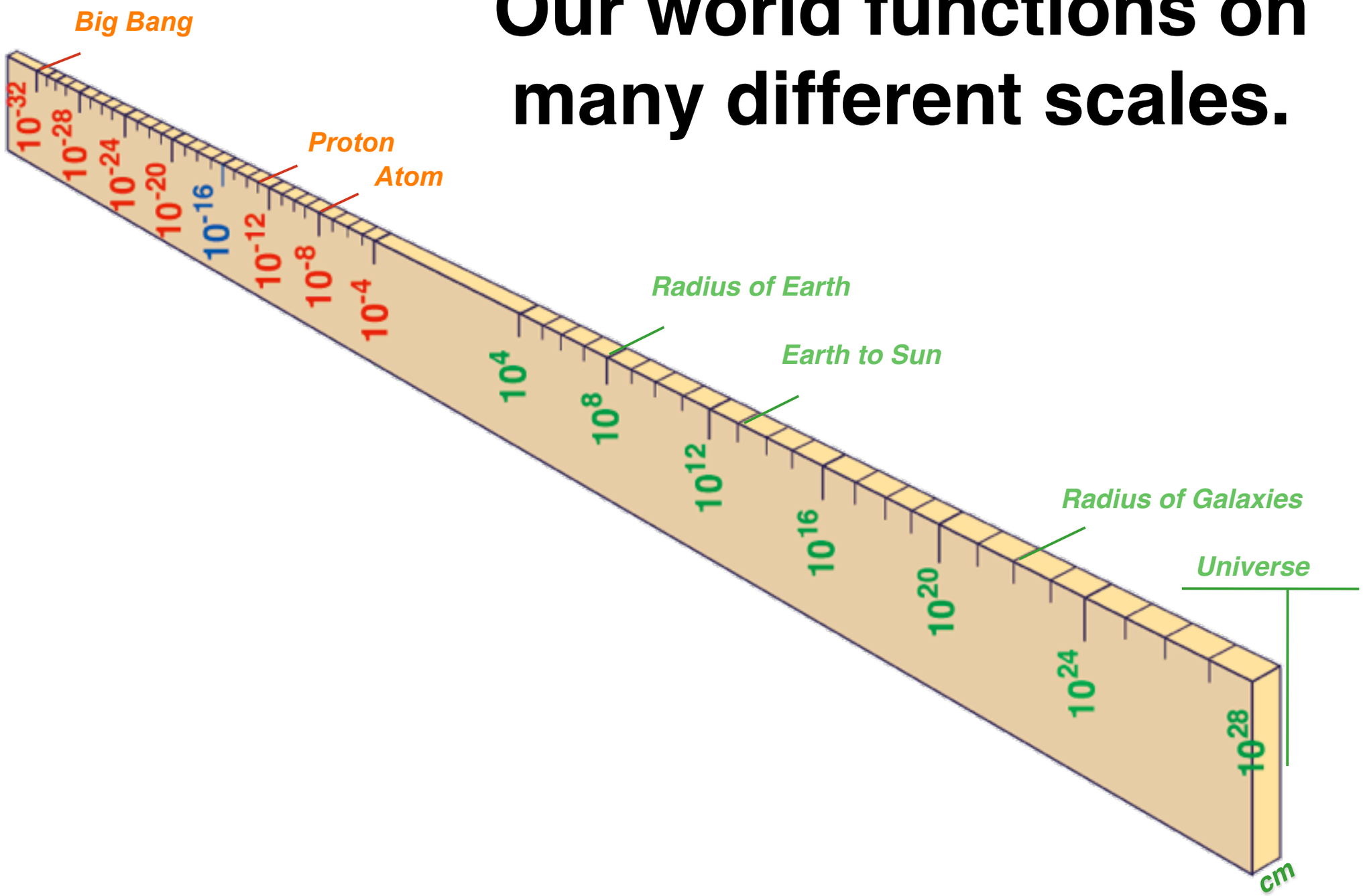
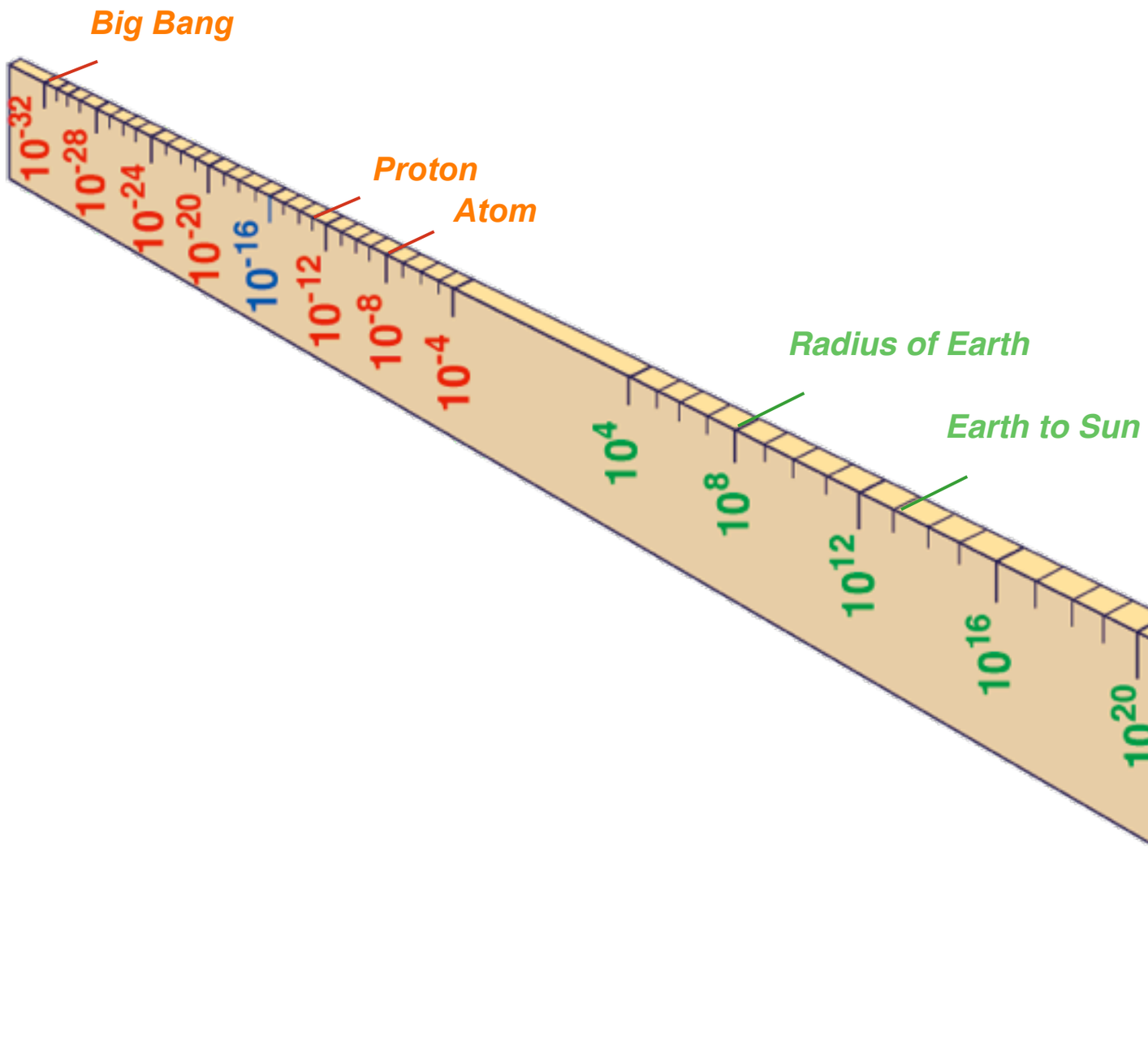
Our world functions on many different scales.



The Scales In Our World

the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY



The Scales In Our World

the ATLAS Experiment

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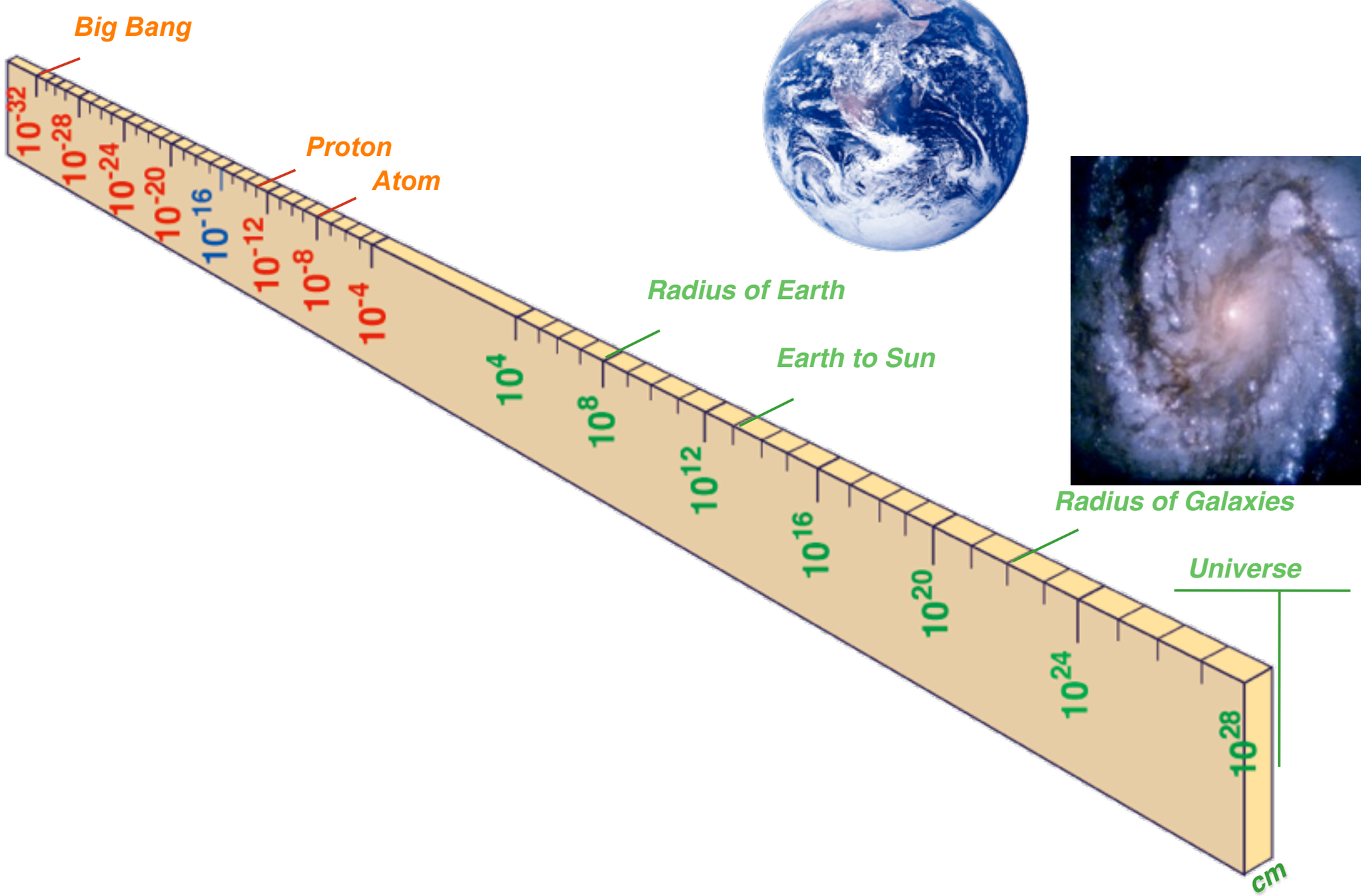

The Scales In Our World

the ATLAS Experiment

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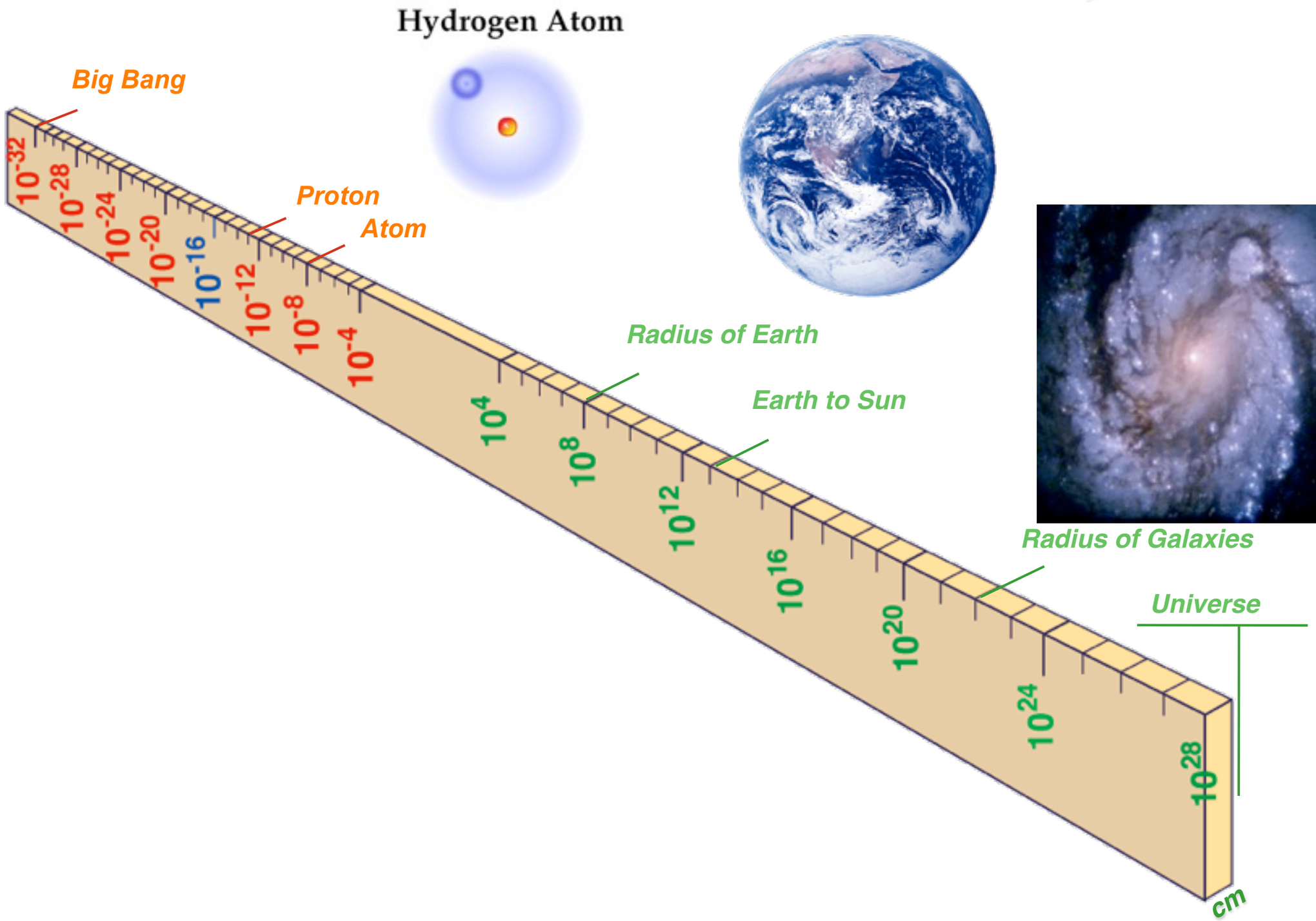

The Scales In Our World

the ATLAS Experiment

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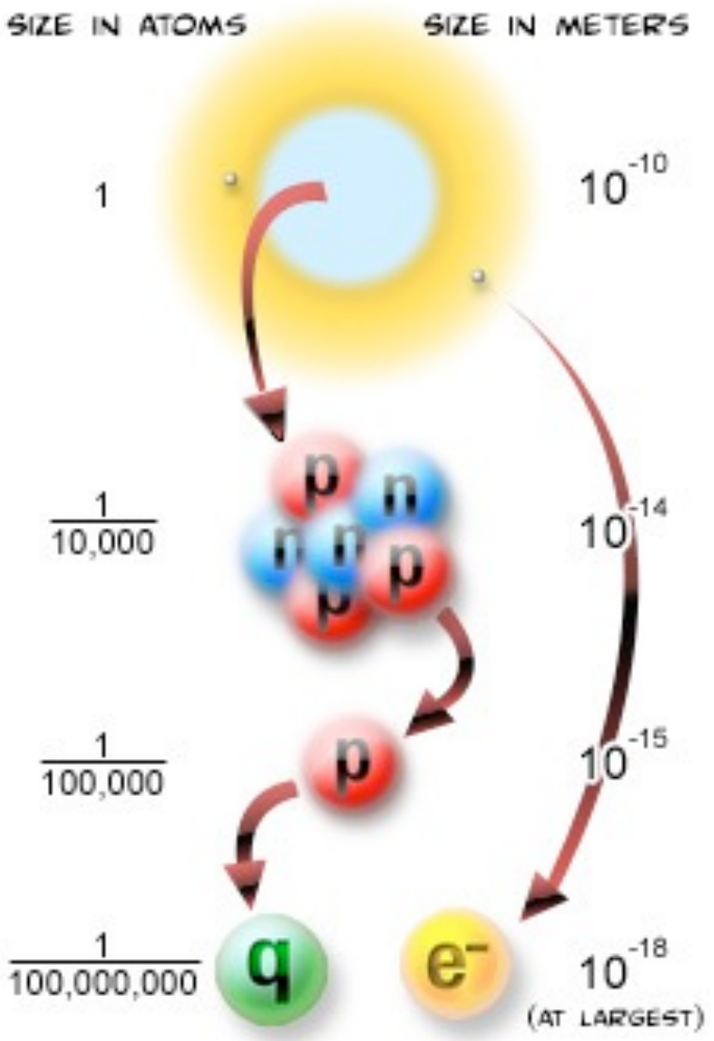
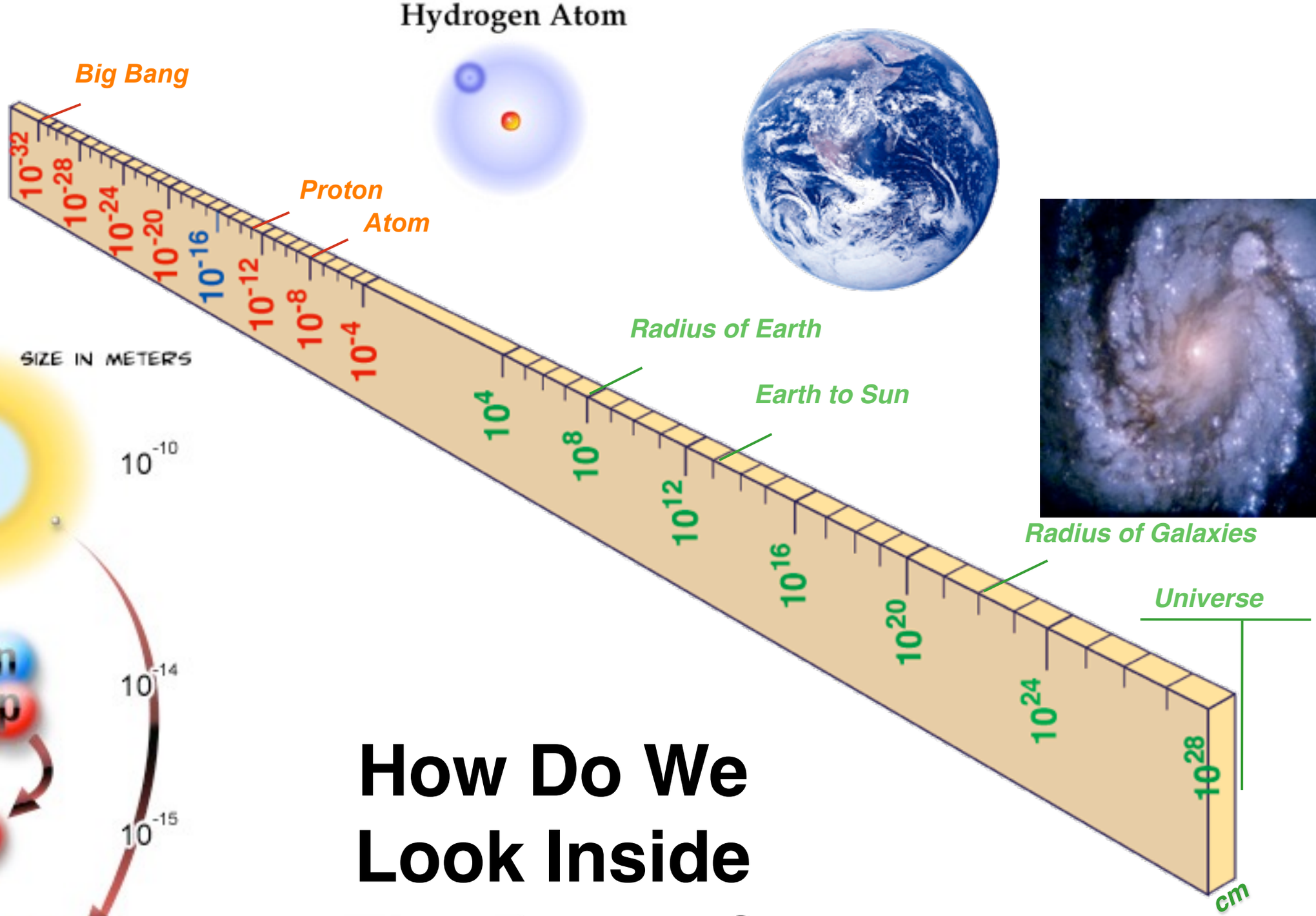


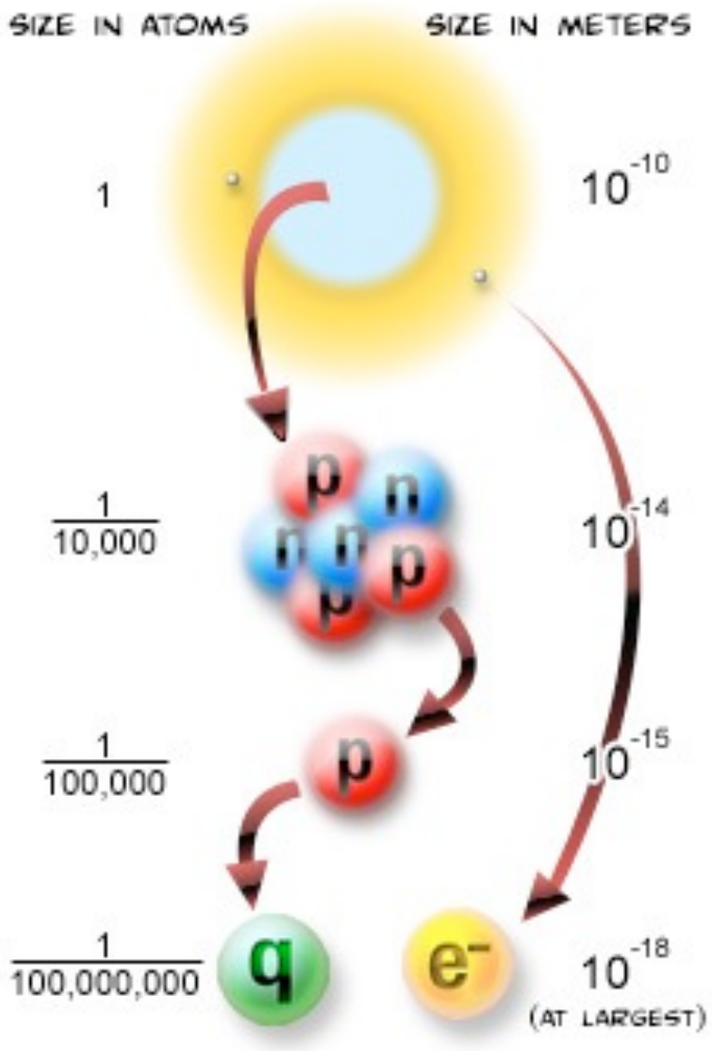


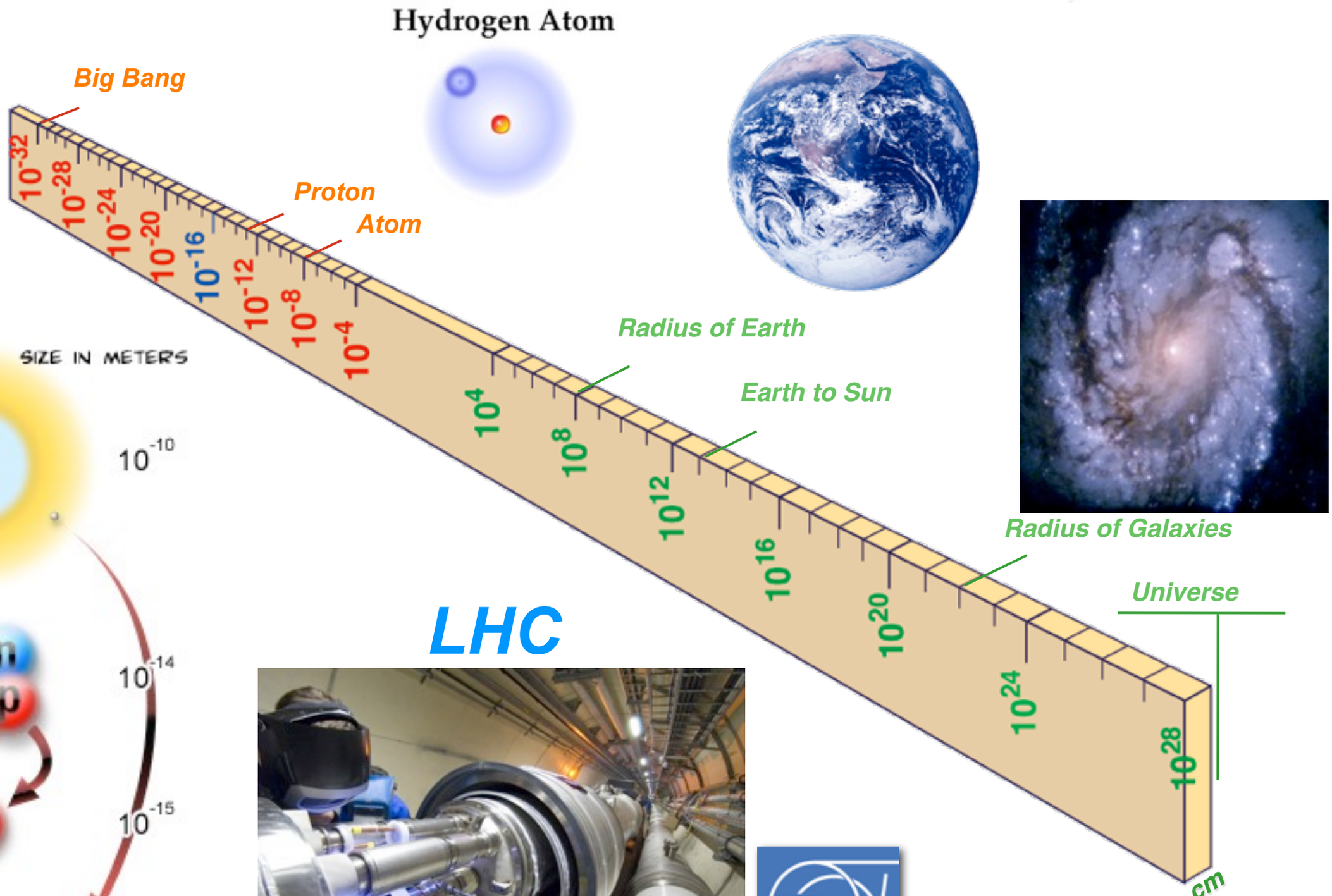
How Do We Look Inside The Proton?

The Scales In Our World

the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY





LHC

CERN

What Do We Know Is There?

the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY

Forces

Particles

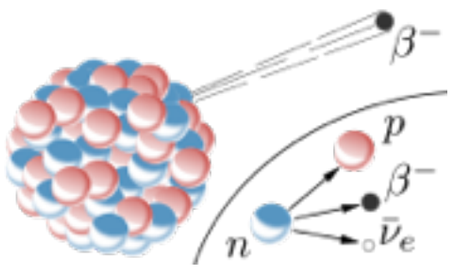
What Do We Know Is There?

the ATLAS Experiment

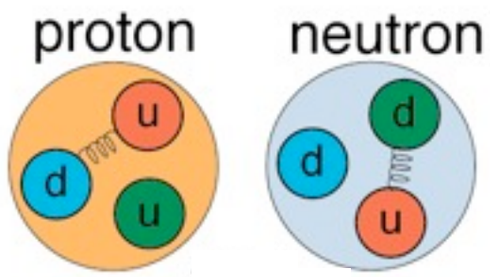
BROOKHAVEN NATIONAL LABORATORY

Forces

Electromagnetism

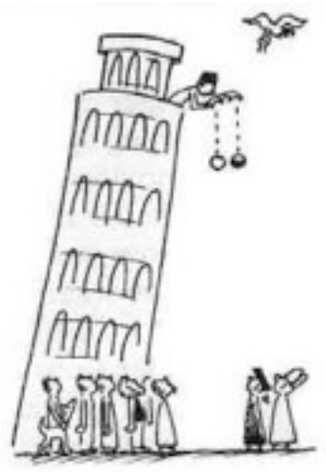


Weak



Strong

Particles



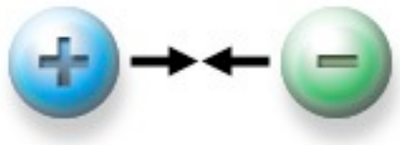
Gravity

What Do We Know Is There?

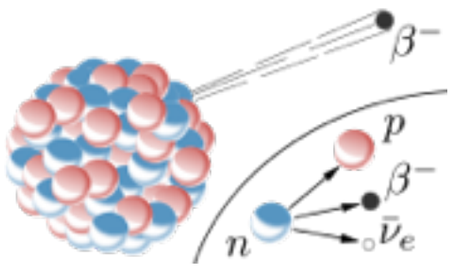
the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY

Forces



Electromagnetism



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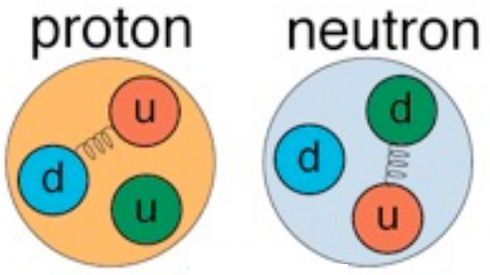
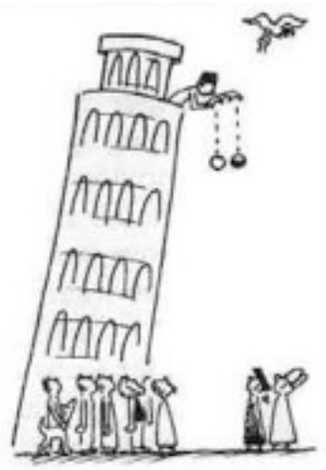
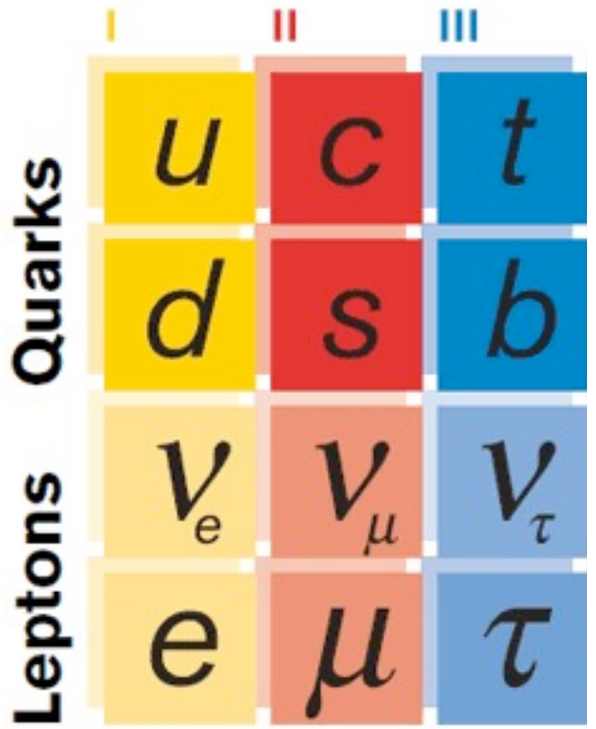


Strong

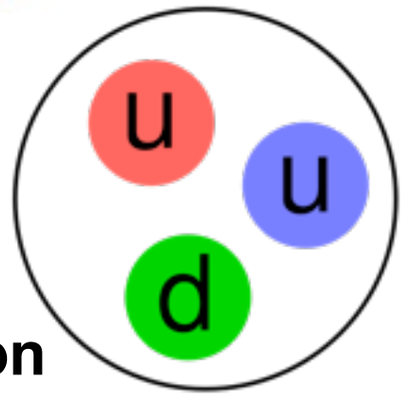


Gravity

Particles



Three Generations of Matter



e.g. Proton

Forces at the Sub-atomic Level

Particles experience a force when a “force carrier” particle interacts with them.

Forces at the Sub-atomic Level

the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY

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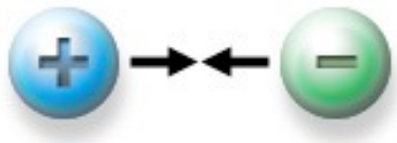

Electromagnetism

photon (γ) exchange

Forces at the Sub-atomic Level

the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY

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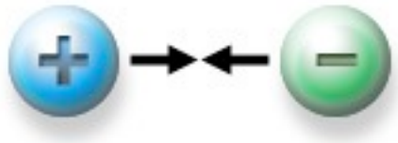
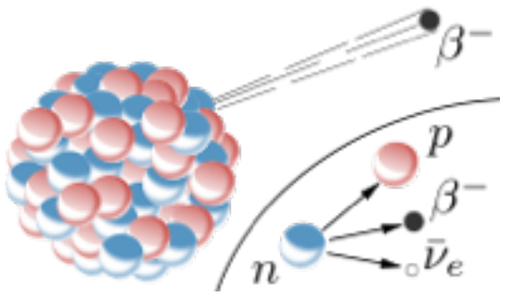
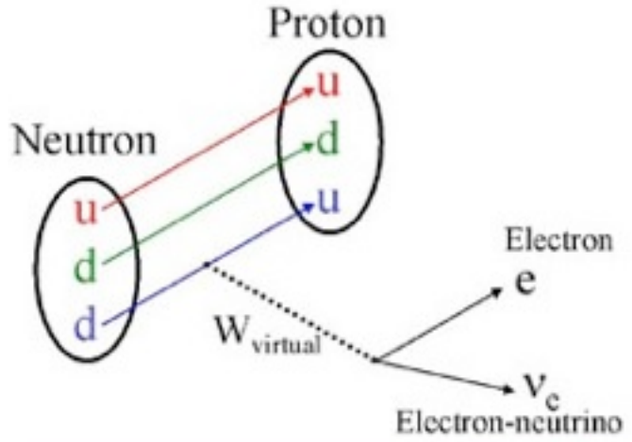


Electromagnetism

photon (γ) exchange



Weak



W± exchange

Forces at the Sub-atomic Level

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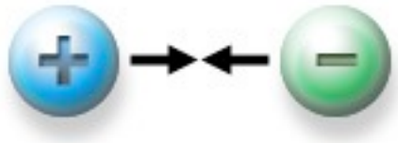
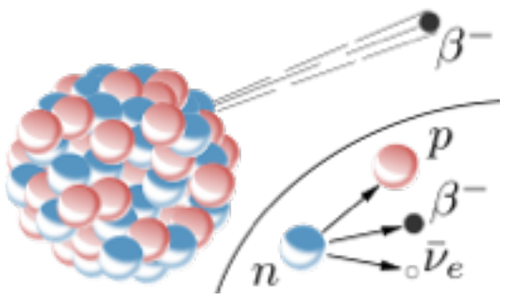


Electromagnetism

photon (γ) exchange



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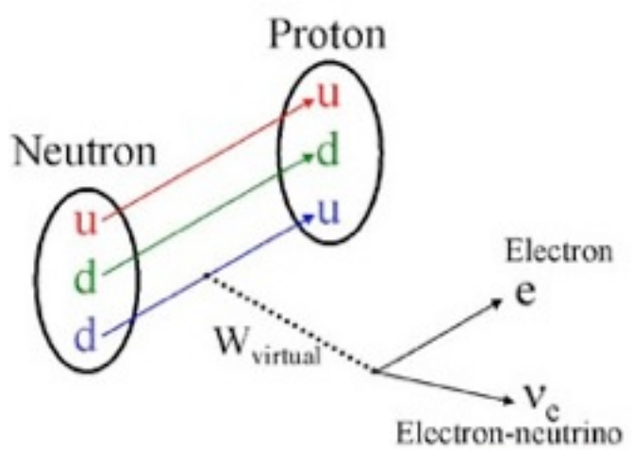
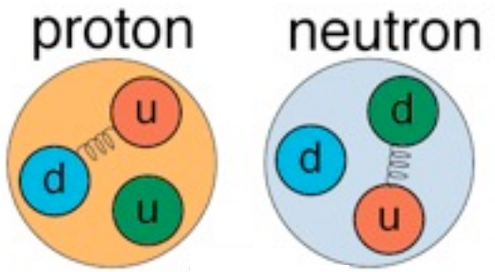
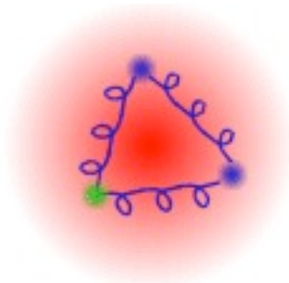


W± exchange



Strong



gluon (g) exchange

Overview

What We Already Know: The Standard Model

Why Do Particles Have Mass?

The Higgs Boson

Elementary Particle Masses

the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY

Over 30 fundamental particles + antiparticles

$$m_{\text{top}} \approx 170 \times m_{\text{proton}}$$

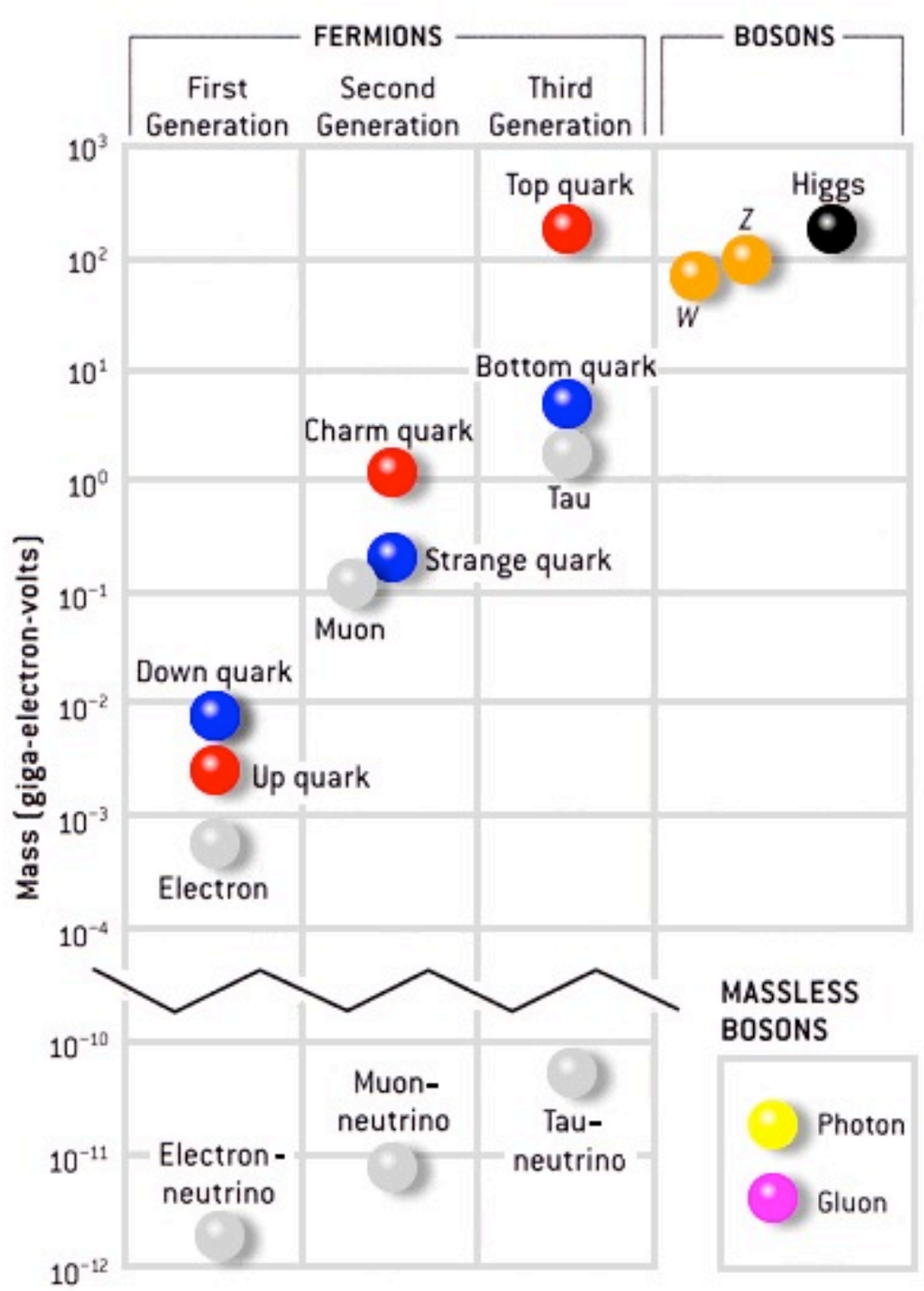
$$m_{\text{charm}} \approx m_{\text{proton}}$$

$$m_{\text{electron}} \approx m_{\text{proton}}/1000$$

$$m_{\text{neutrino}} \approx m_{\text{proton}}/100,000,000,000$$

$$m_{\text{photon,gluon}} = 0$$

Why?



The Story of Mass

the ATLAS Experiment

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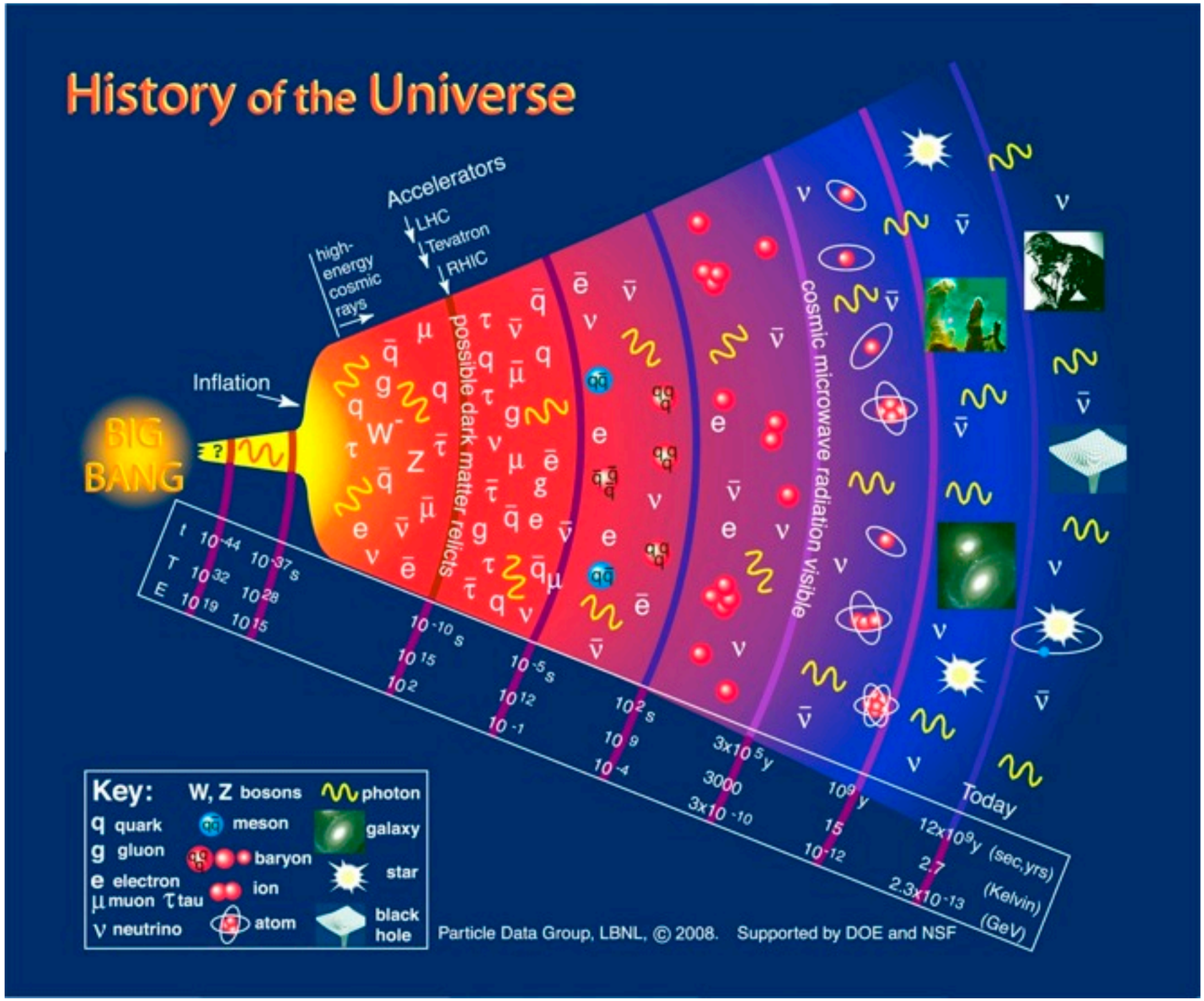
The Big Bang

Massless Particles



Today

Massive Particles

time →

The Story of Mass

the ATLAS Experiment

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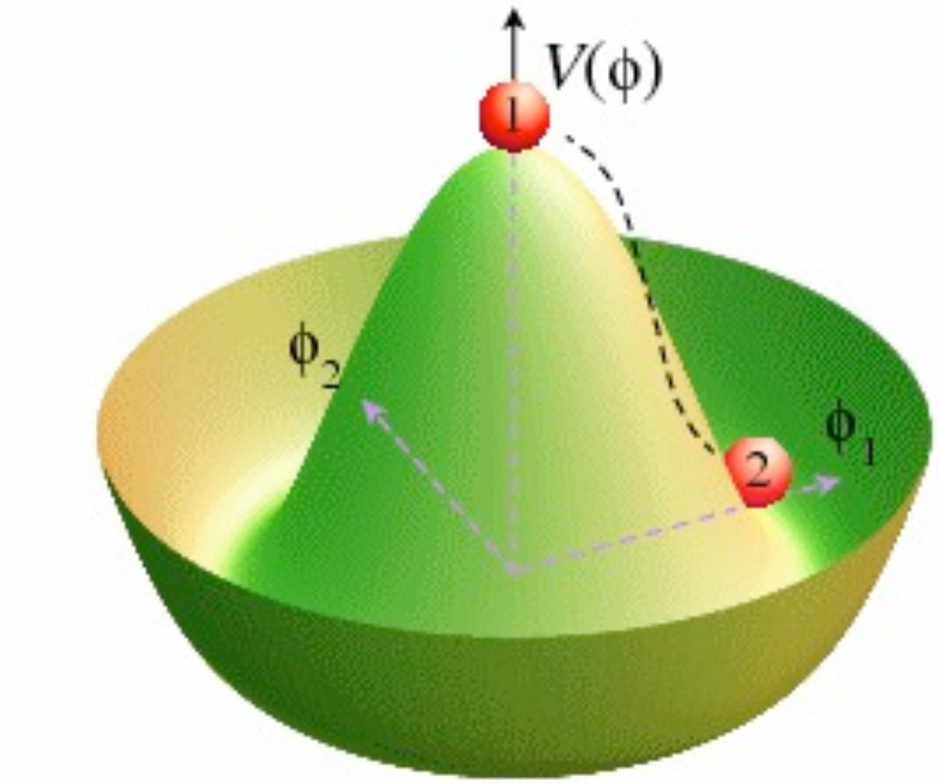
≈10^{-12} seconds after the Big Bang
a new field permeates space and
starts interacting with certain particles.



The Big Bang

Massless Particles

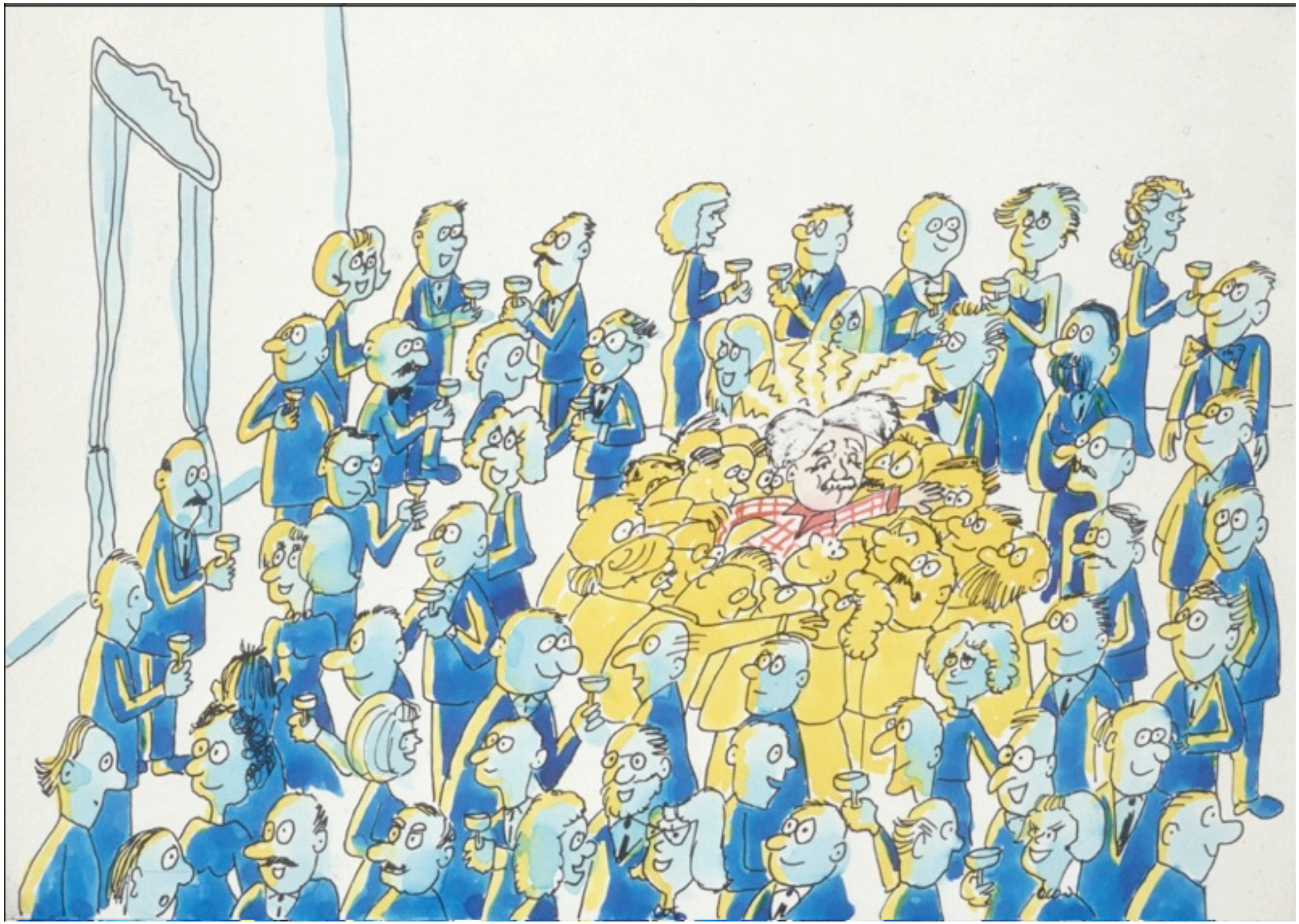
Today

Massive Particles

The “force” that these particles feel is mass!

The Higgs Field

The Higgs Field



Overview

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Why Do Particles Have Mass?

The Higgs Boson

The Higgs Boson

If the Higgs field is there then we should also see a new particle called the ***Higgs Boson***.

How do we find it?

Search for the Higgs Boson

the ATLAS Experiment

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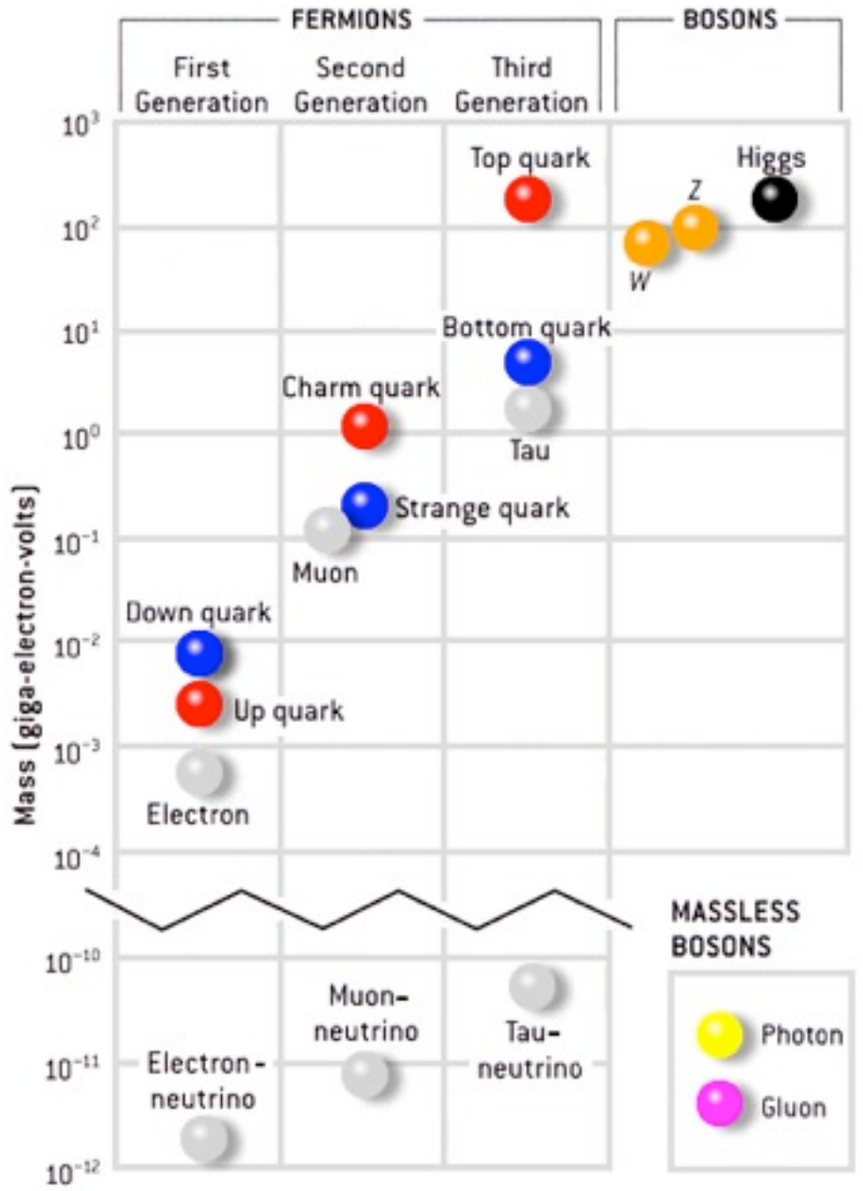
The Higgs Boson wants to decay into massive particles (the more mass the better!)



Search for the Higgs Boson

the ATLAS Experiment

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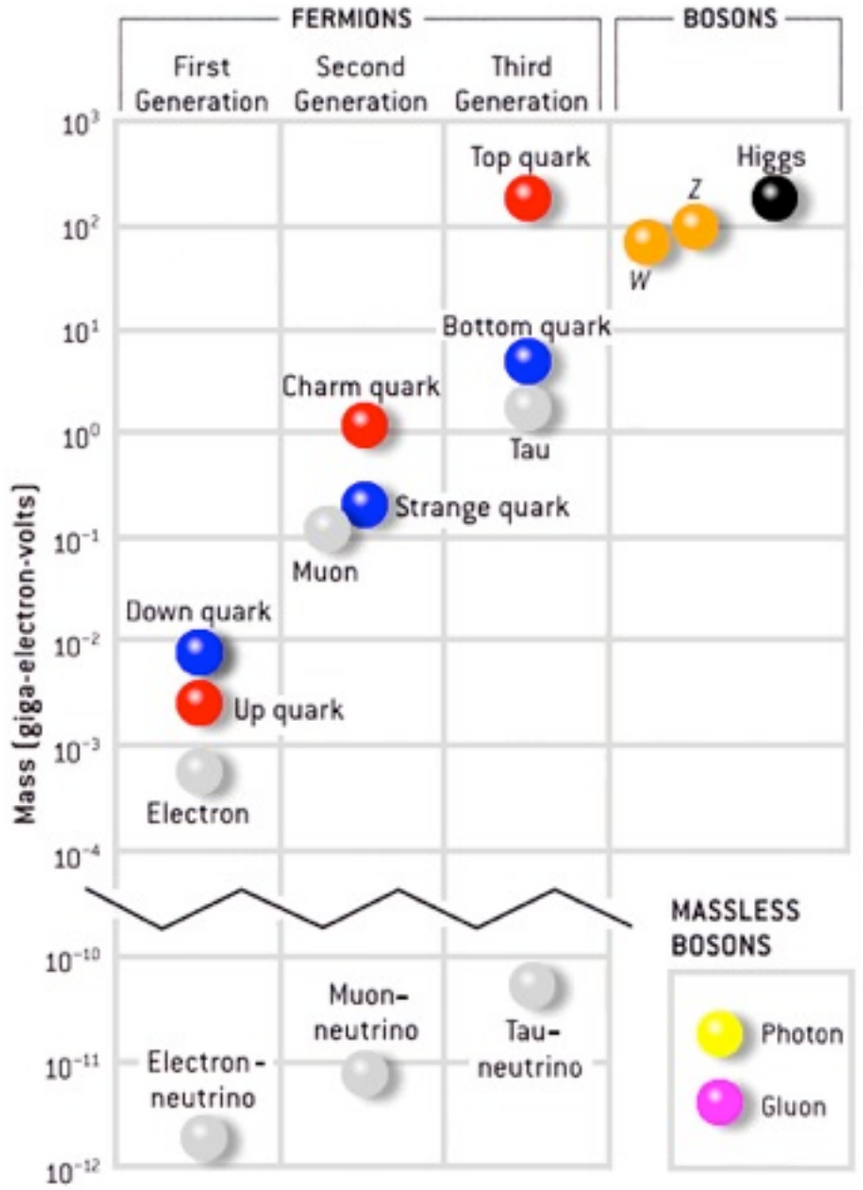
The Higgs Boson wants to decay into massive particles (the more mass the better!)

Previous experiments tell us that

$$m_W < m_{\text{Higgs}} < m_{\text{top}}$$



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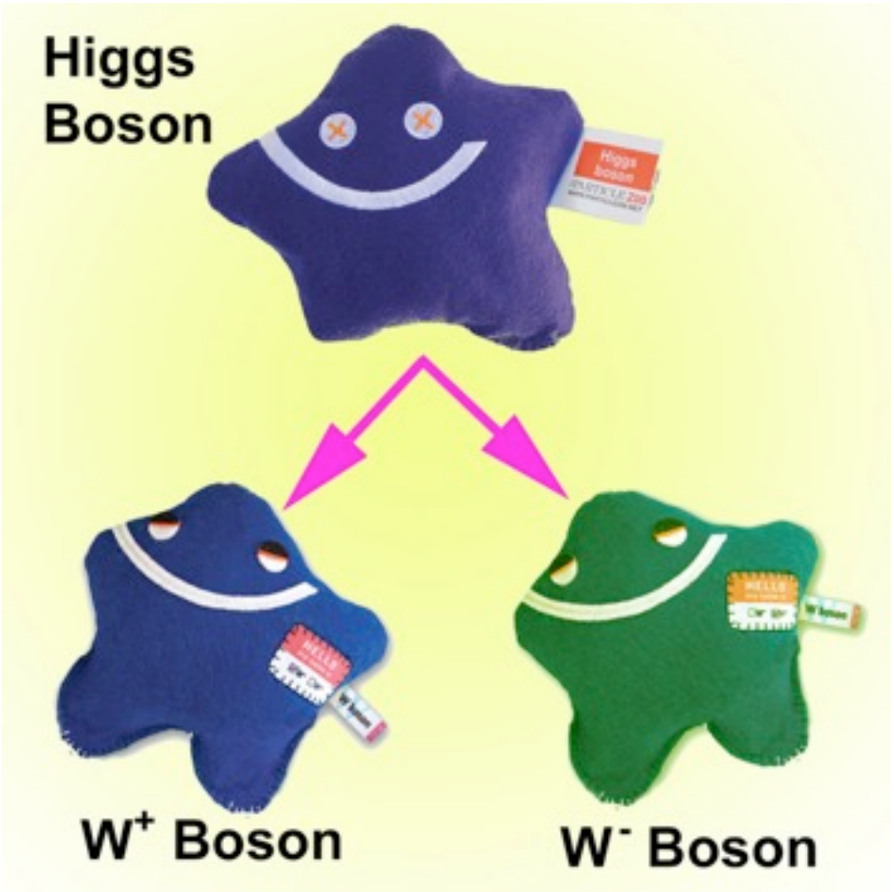
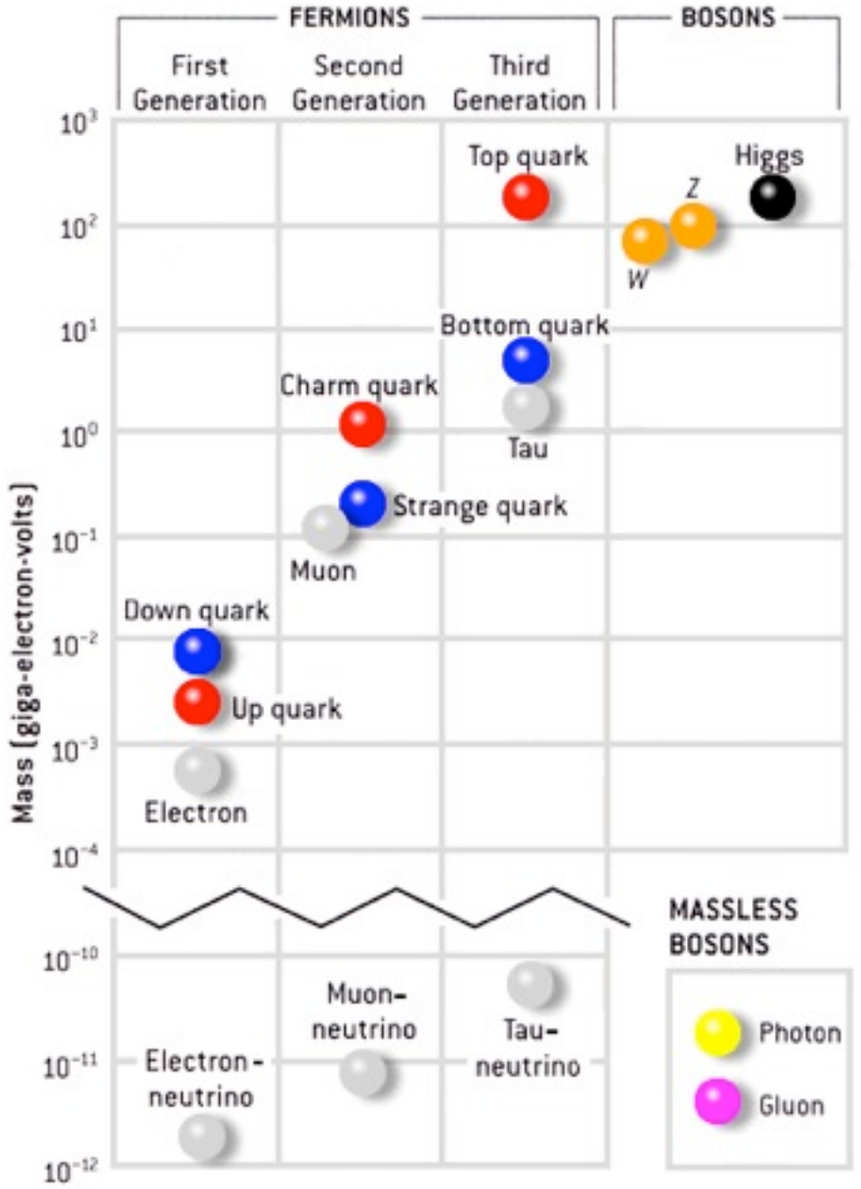
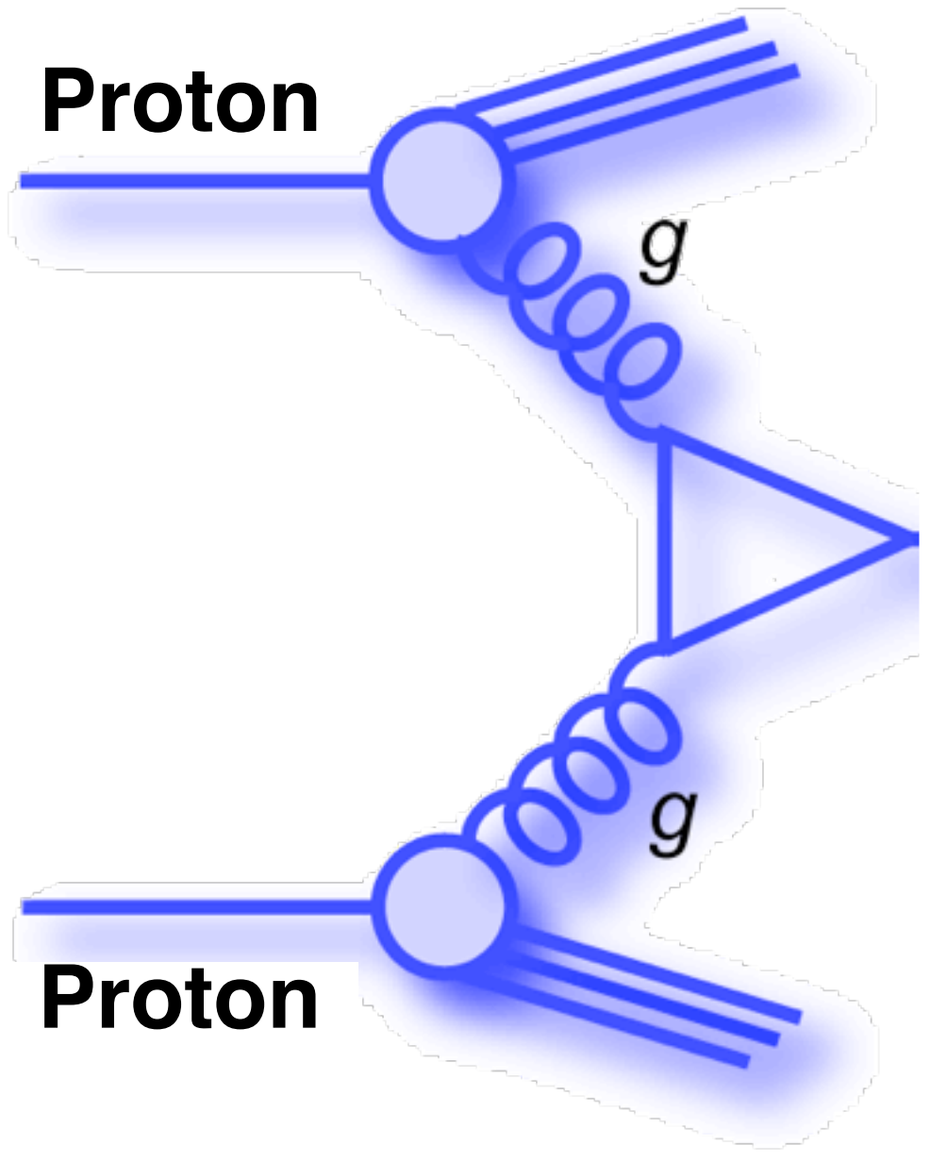




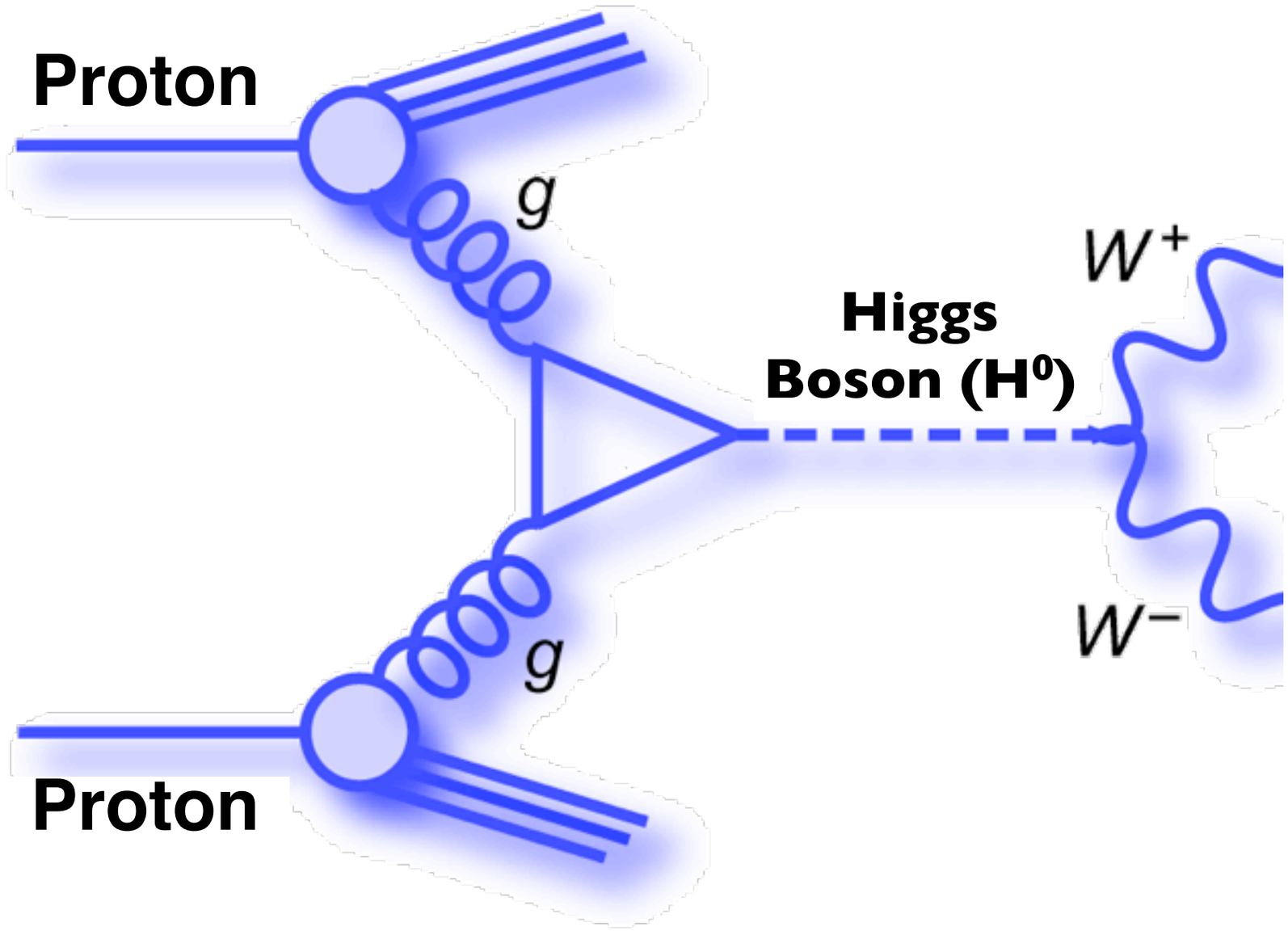
Higgs Event



1) proton + proton collision

time →

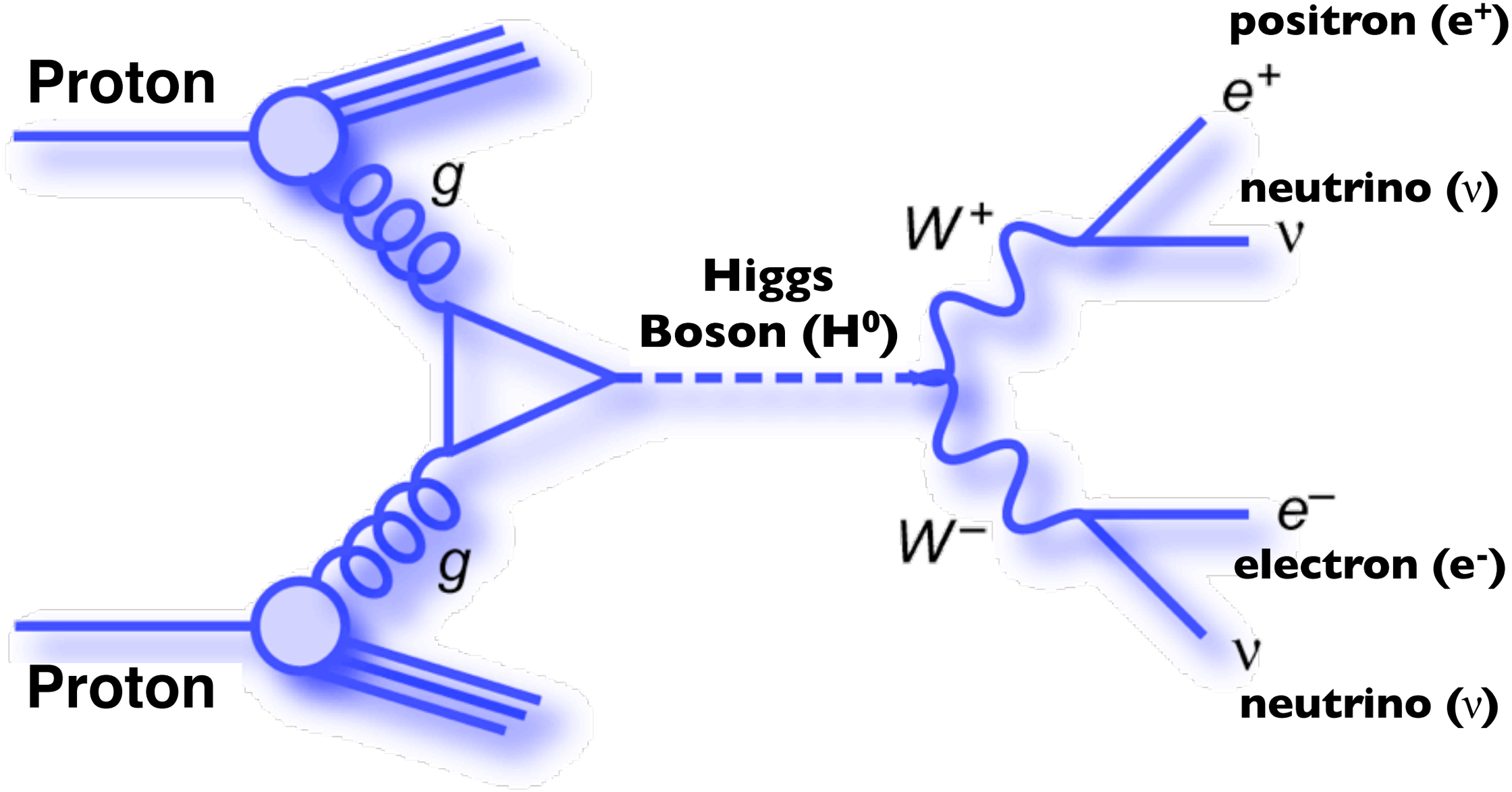
Higgs Event



2) Higgs decays to W^+ and W^-

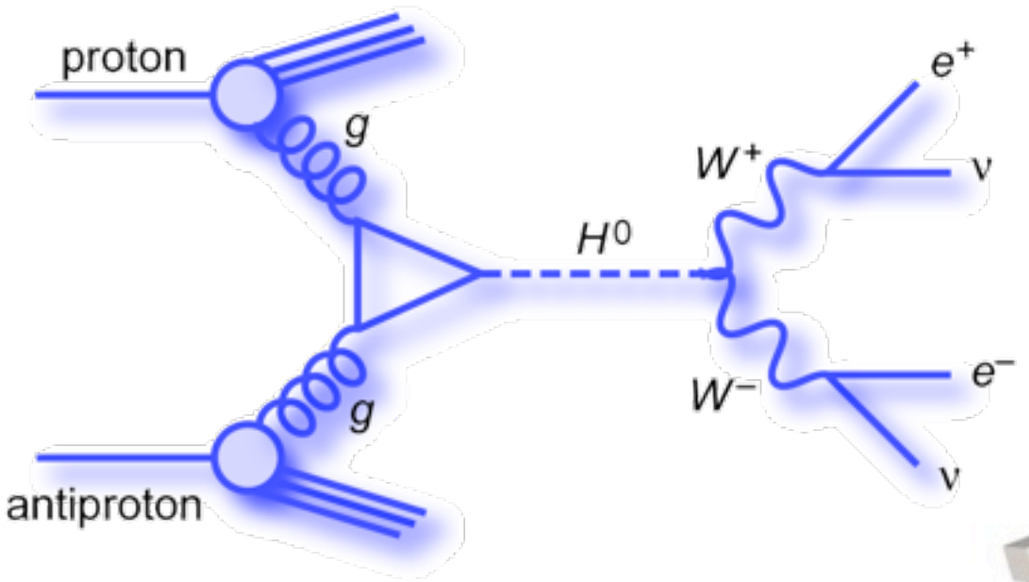
time →

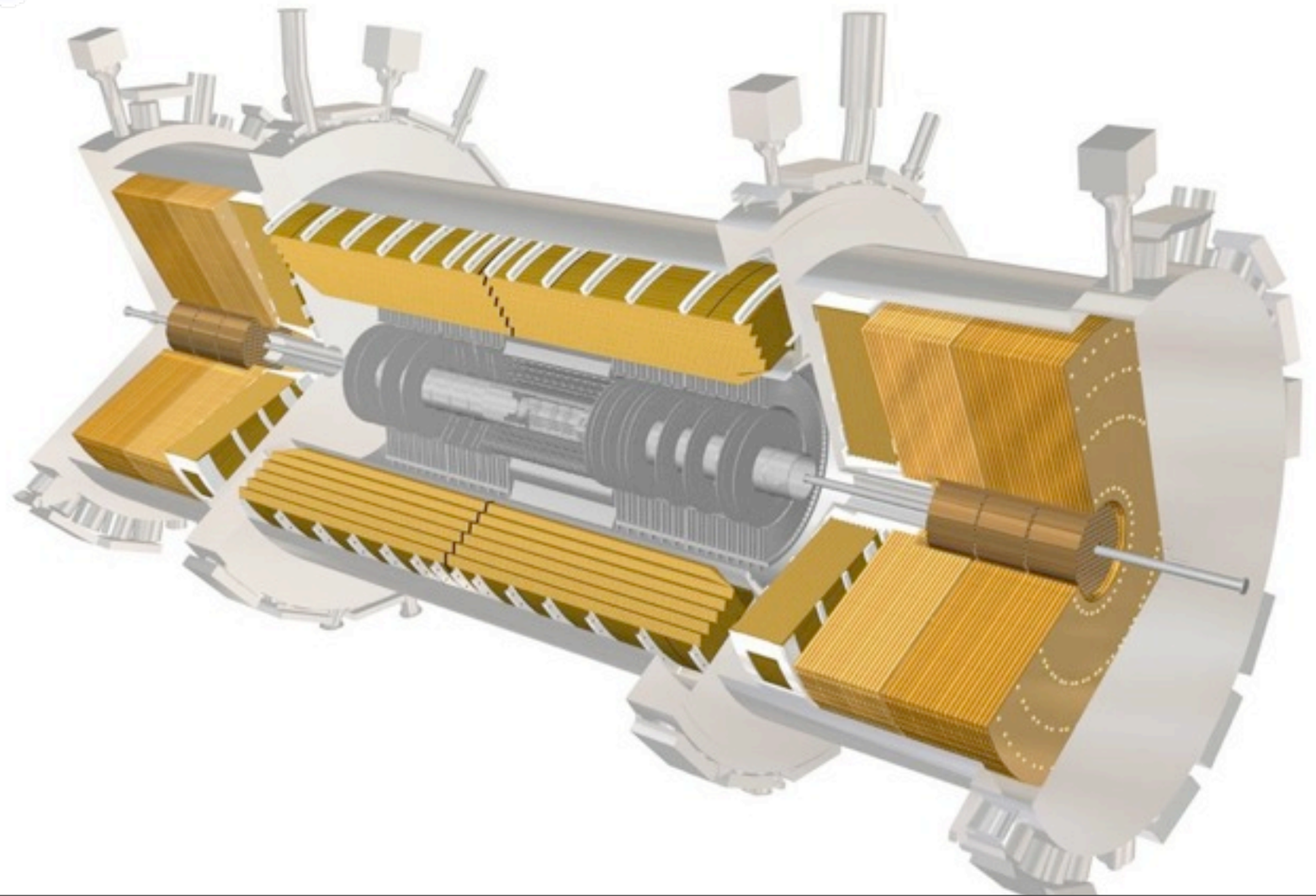
Higgs Event



time →

Event Reconstruction

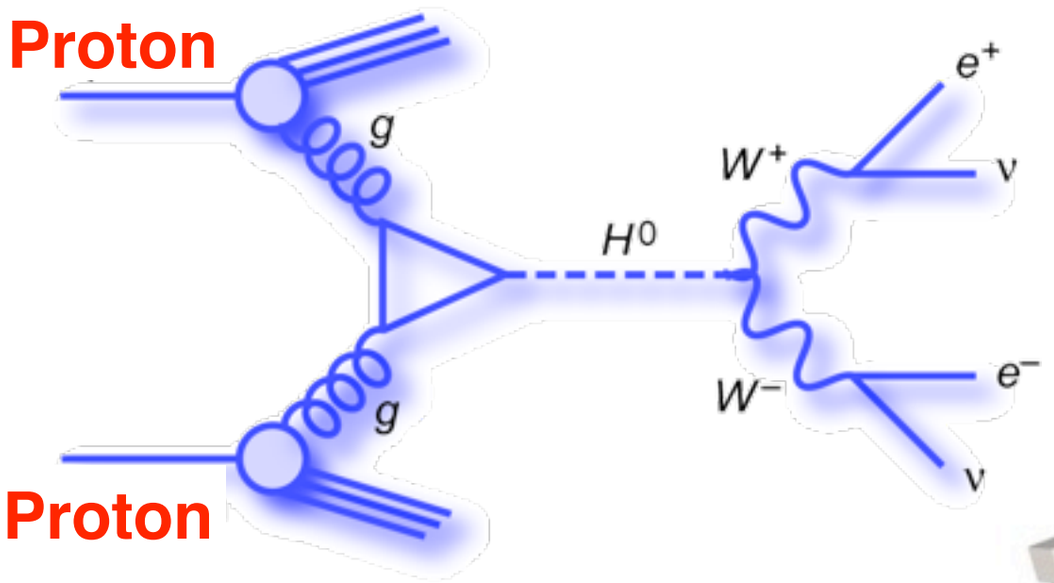




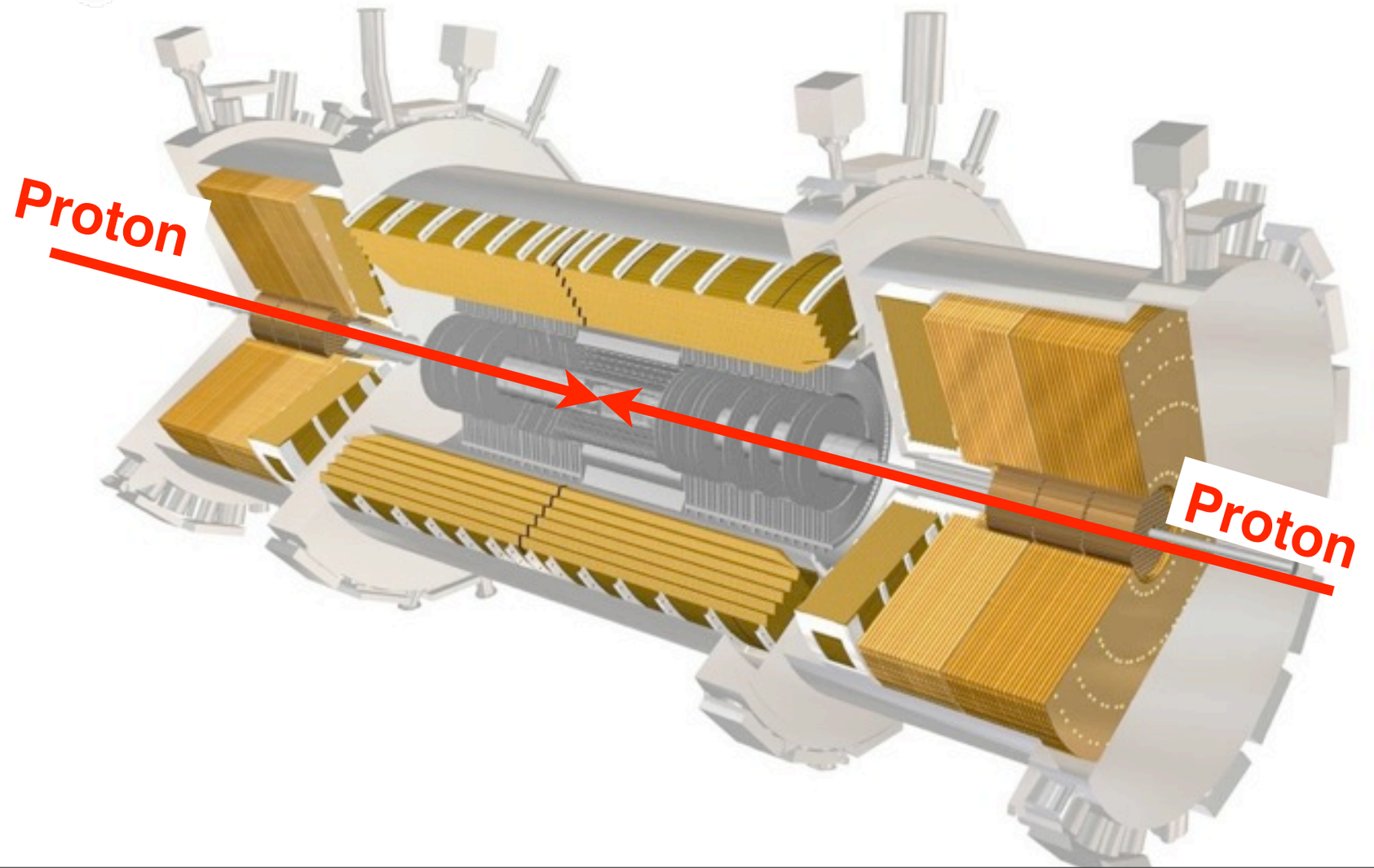
Event Reconstruction

the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY



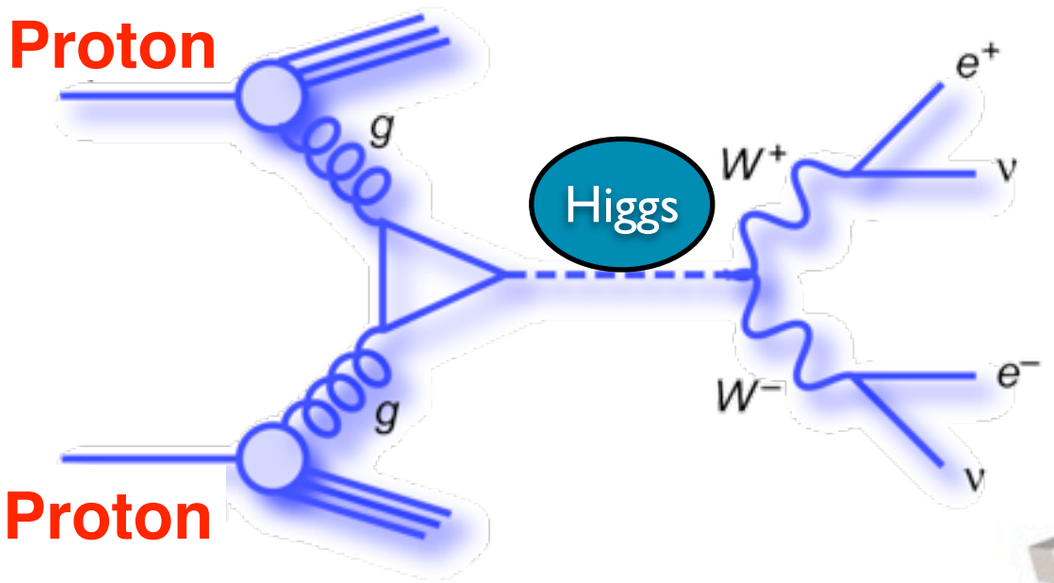
Protons collide in the center of the detector.



Event Reconstruction

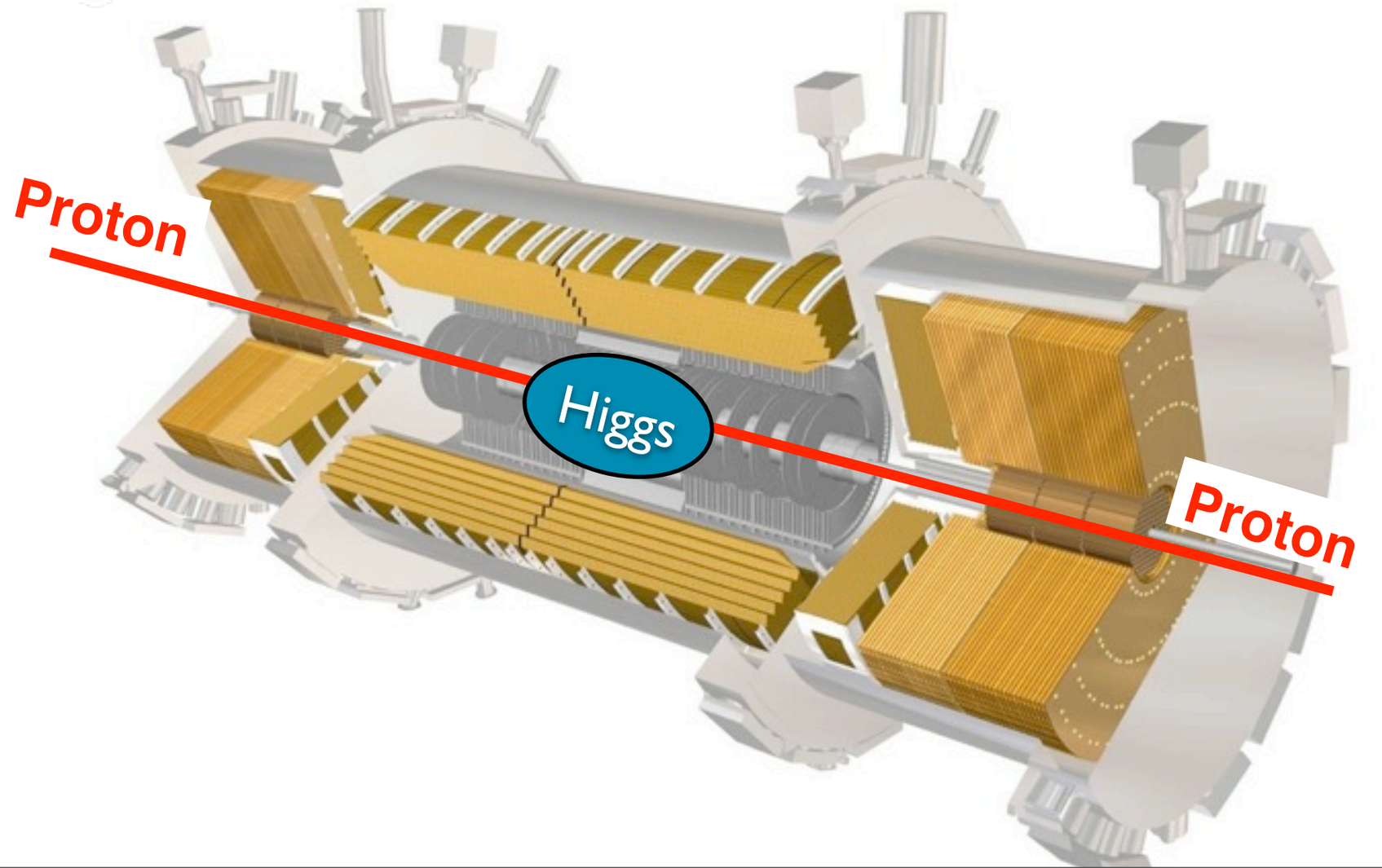
the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY



Protons collide in the center of the detector.

Higgs is produced and decays to 2 W bosons.



Event Reconstruction

the ATLAS Experiment

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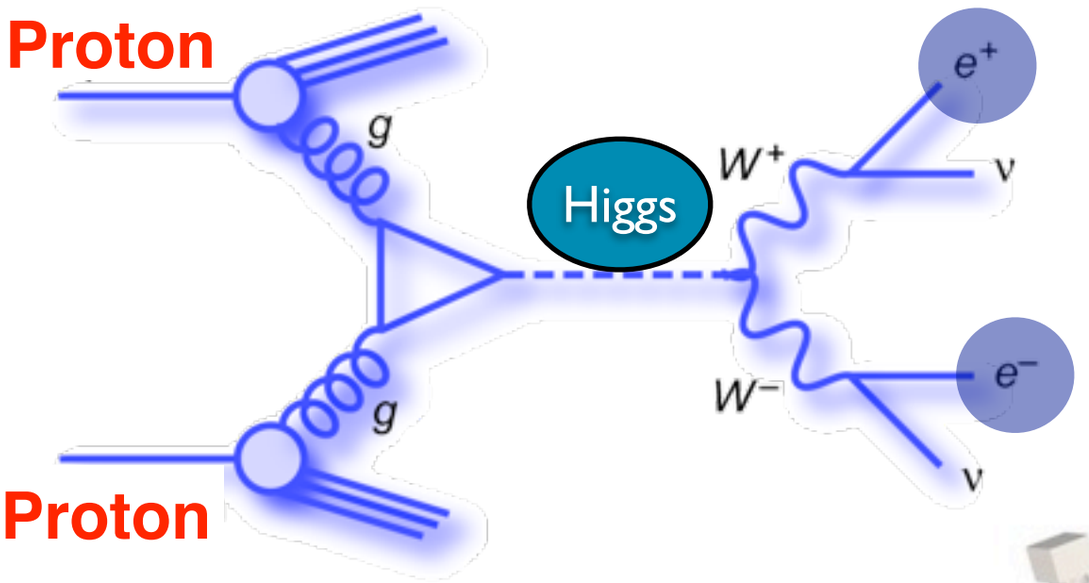
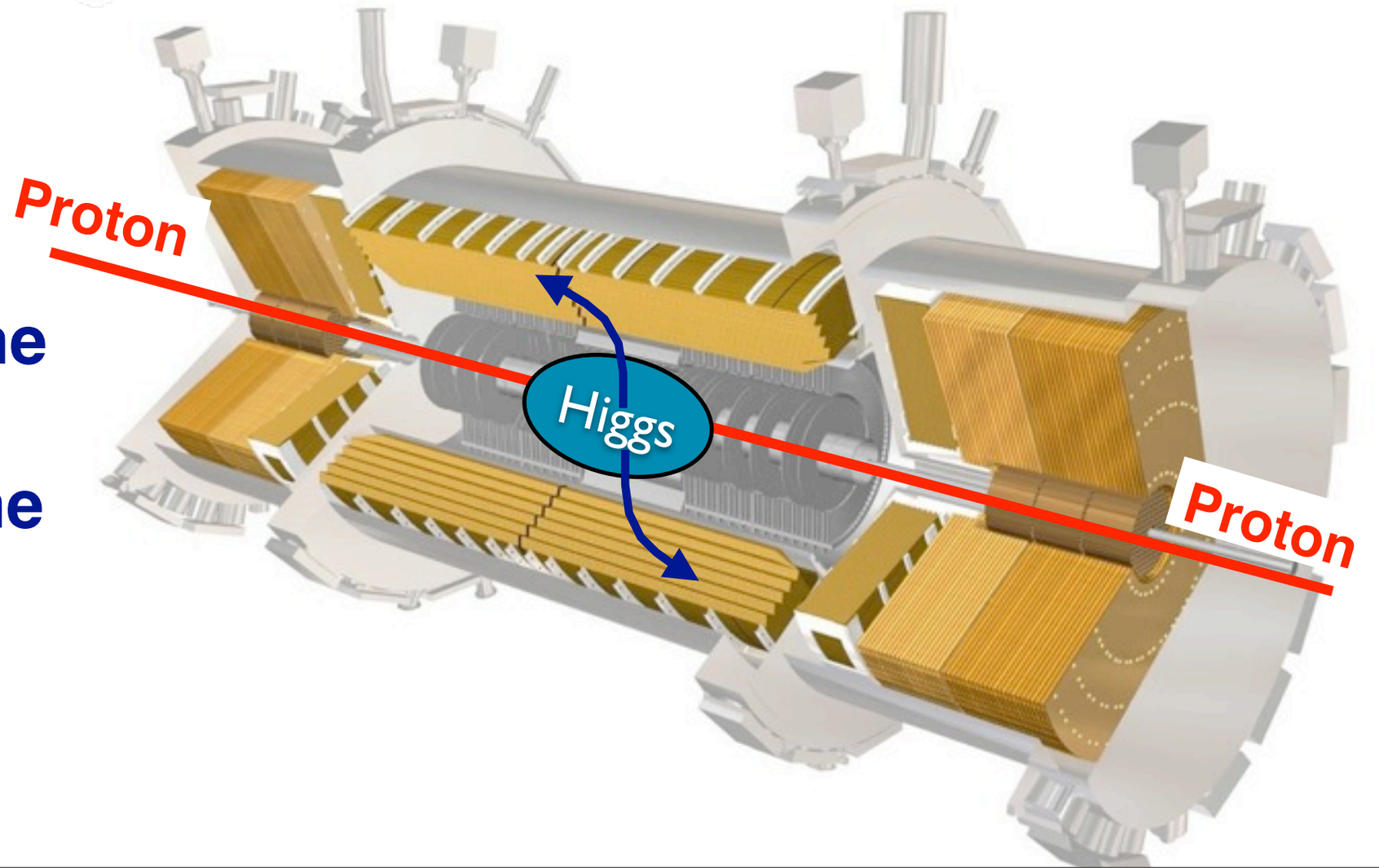


Protons collide in the center of the detector.

Higgs is produced and decays to 2 W bosons.

Electrons bend in the magnetic field and deposit energy in the calorimeter.



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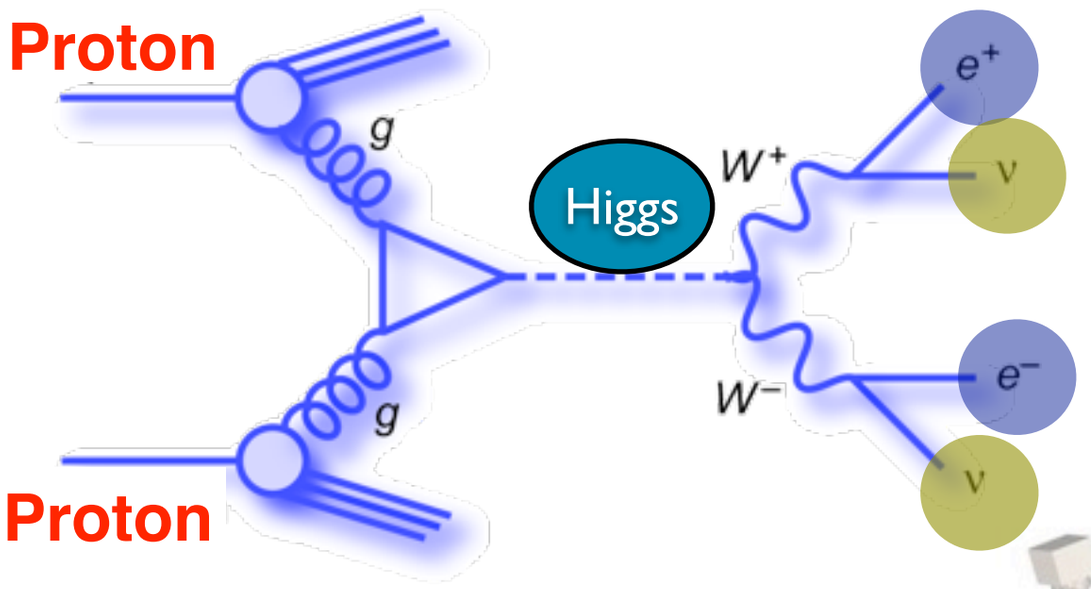

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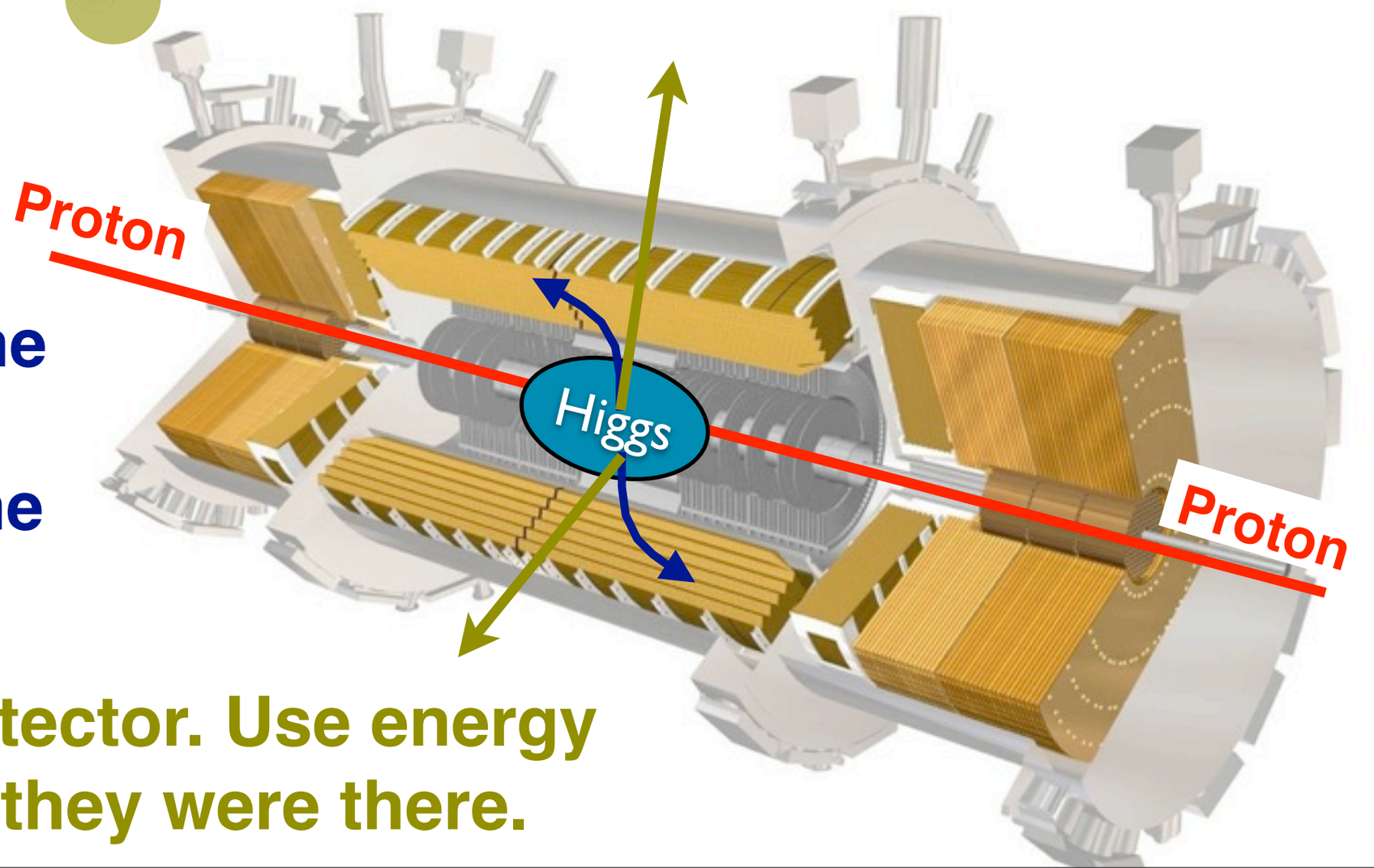


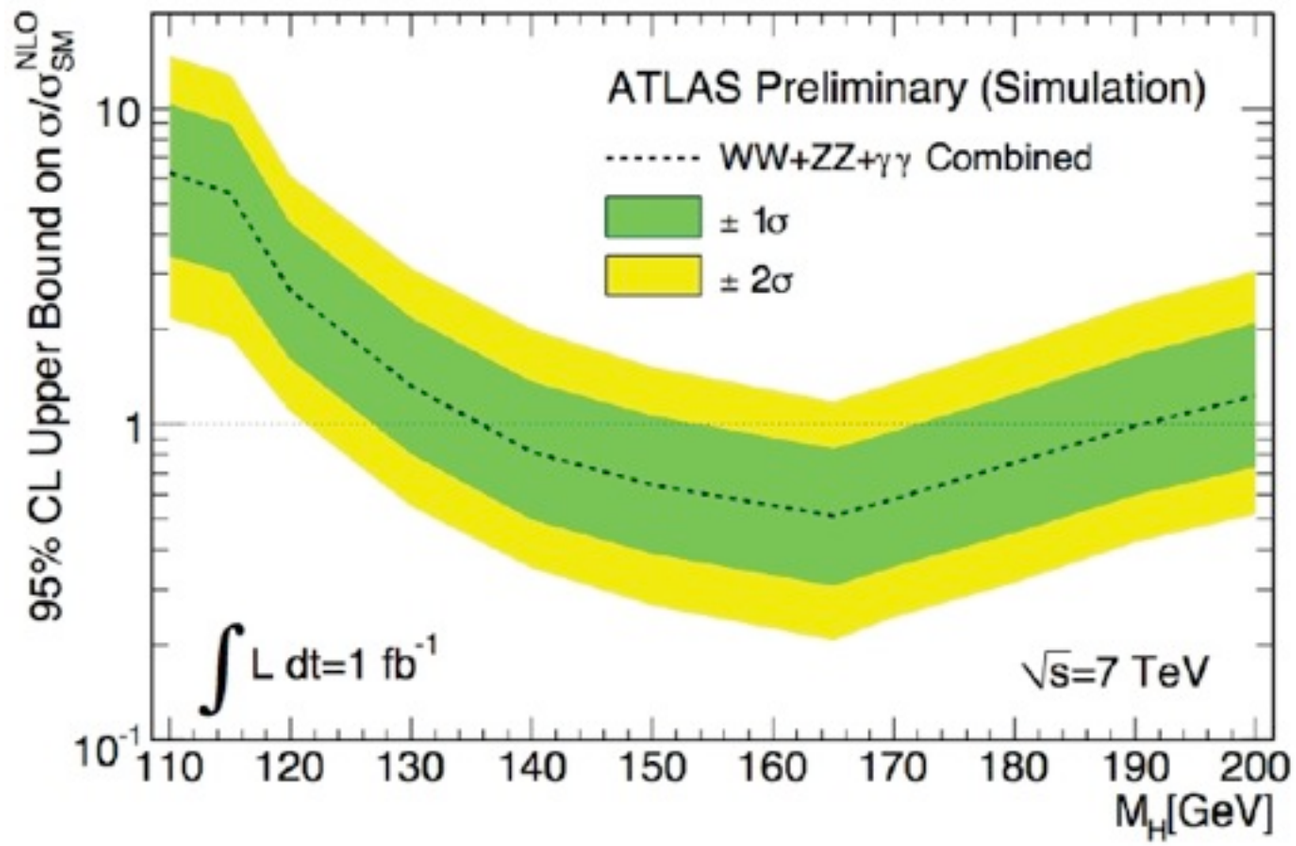
Electrons bend in the magnetic field and deposit energy in the calorimeter.

Neutrinos escape detector. Use energy imbalance to infer they were there.

When Will We Know?

the ATLAS Experiment

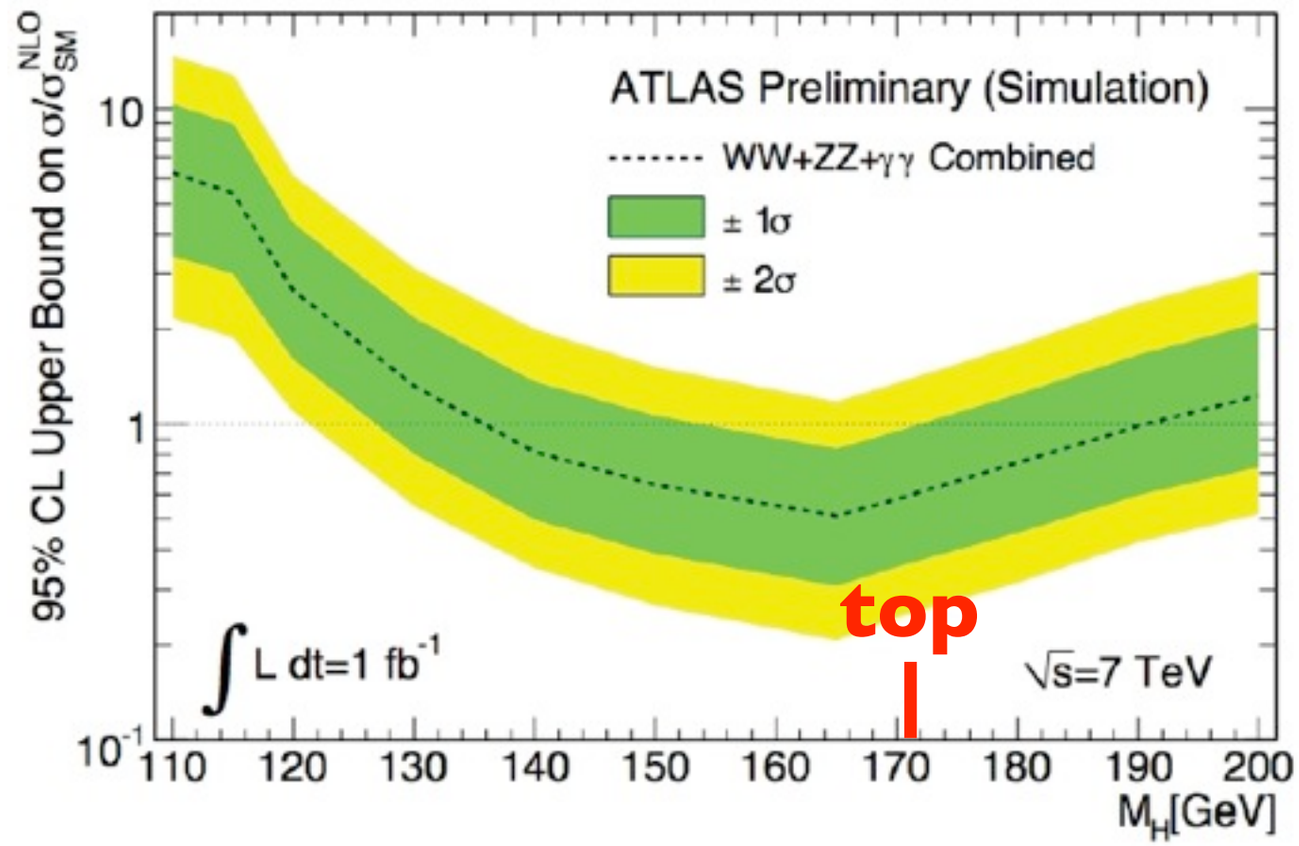
BROOKHAVEN NATIONAL LABORATORY



The answer depends on its mass.

When Will We Know?

The answer depends on its mass.



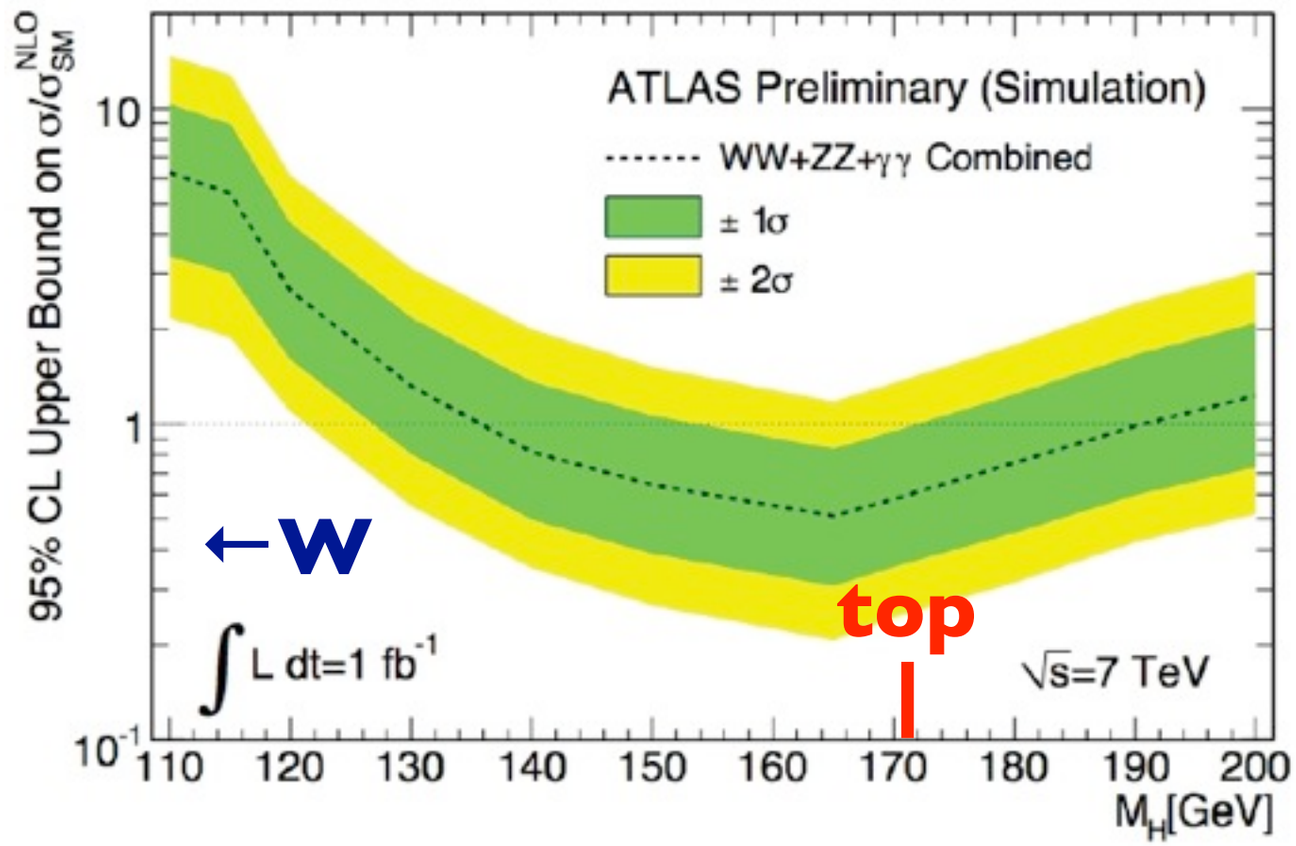
If it's heavy (close to the top quark) we might see it in 2011-2012.

When Will We Know?

the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY

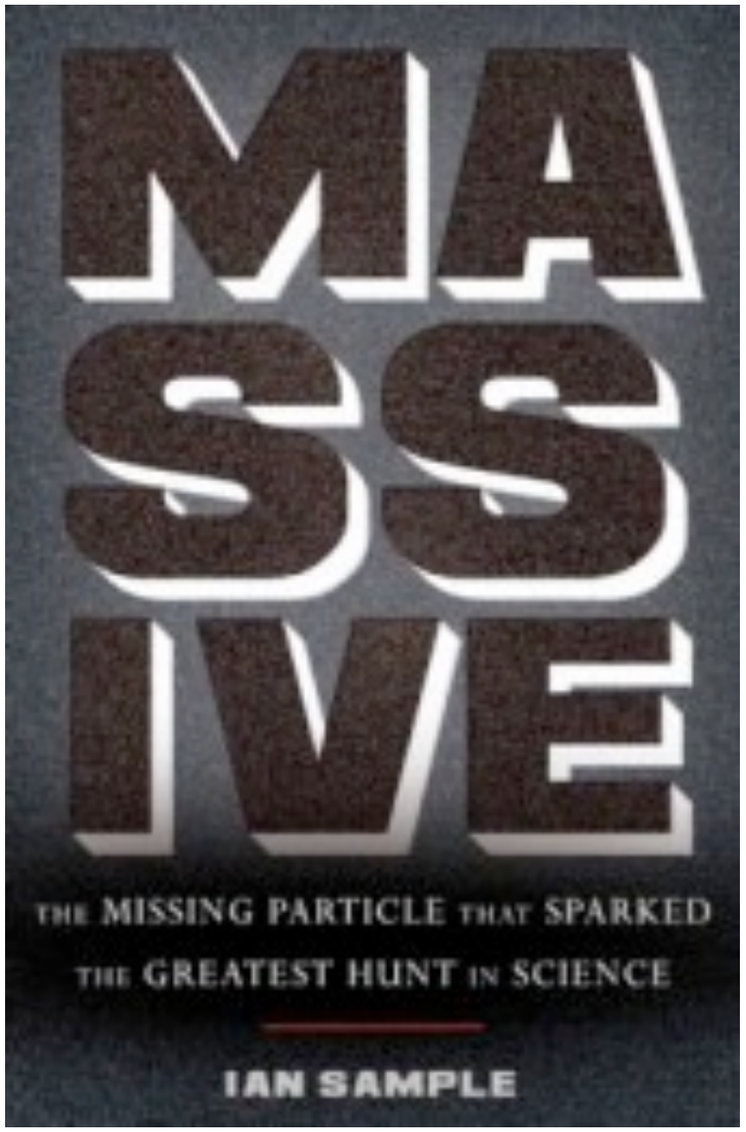
The answer depends on its mass.



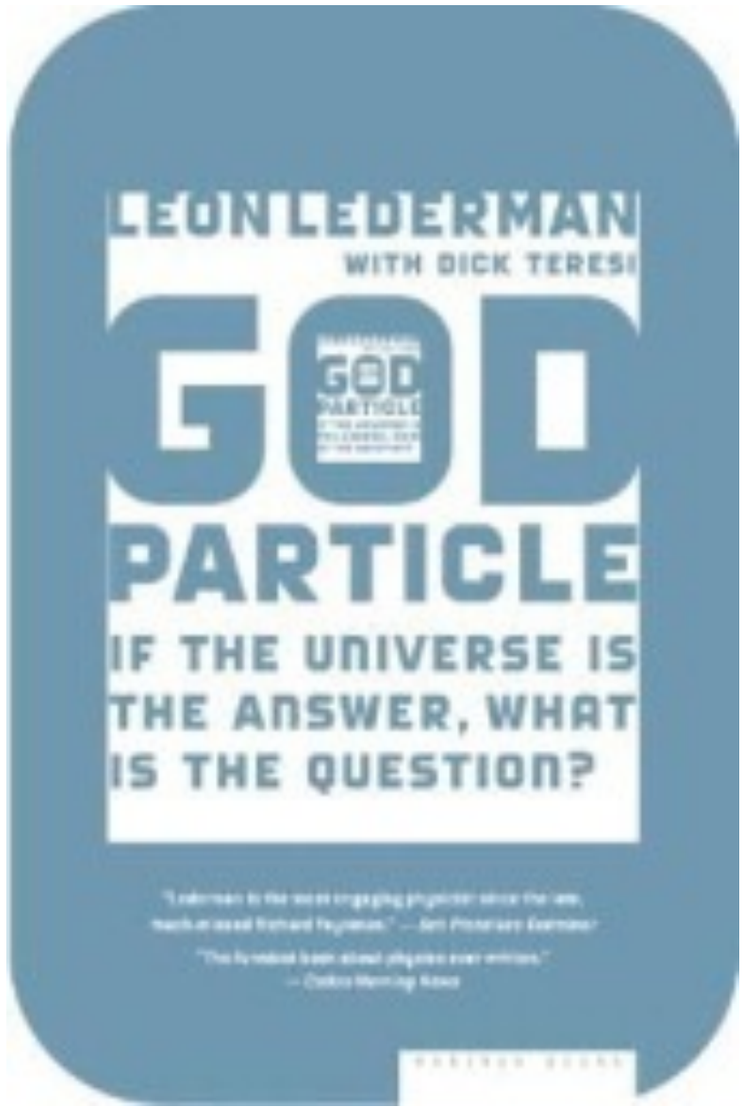
If it's heavy (close to the top quark) we might see it in 2011-2012.

If it's light (close to the W) we might not see it until 2016.

More Higgs @ Borders



by Ian Sample



by Leon Lederman

Is There More To Find?

the ATLAS Experiment

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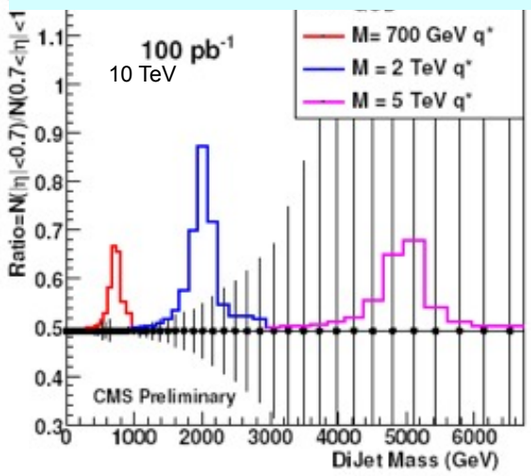
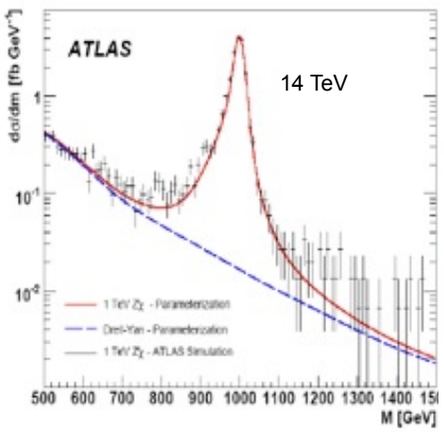
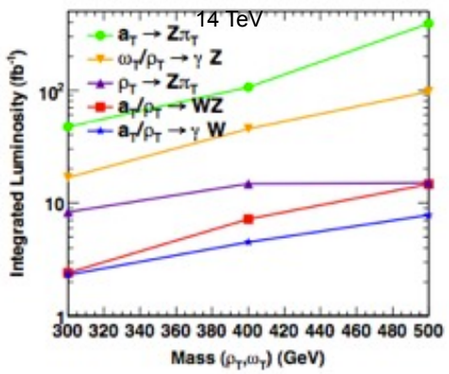
Contact Interaction /Excited Quarks?



New Gauge Bosons?

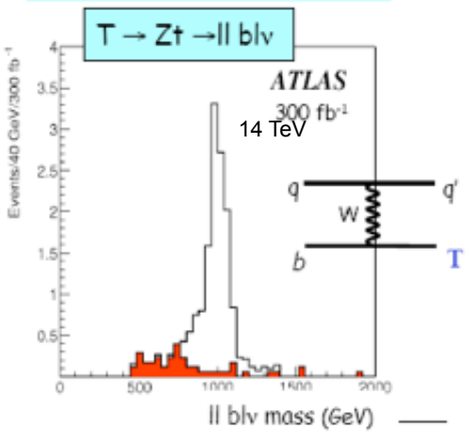


Technicolor?

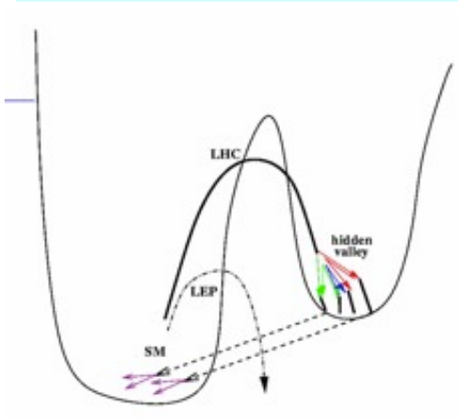


Split Susy?

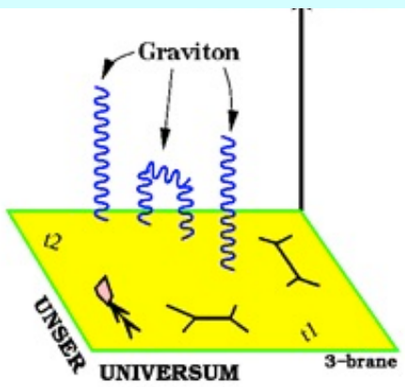
Little Higgs?



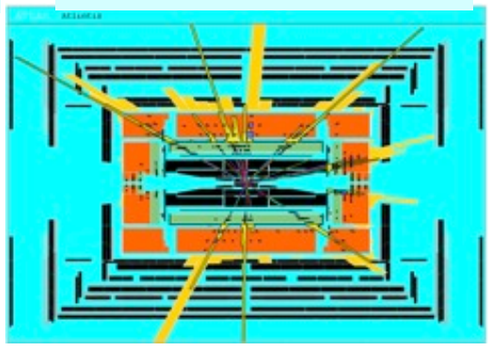
Hidden Valley??



Extra Dimensions?



Black Holes???



Next, you'll hear about a hypothetical particle called a *leptoquark* and why we might find it soon at ATLAS